Hardware Developments for Fruits and Vegetables Quality Determination

by

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CERTIFICATION OF APPROVAL

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Approved by,

(Dr John Ojur Dennis)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Zizie Zulaiqa Ahmad

ABSTRACT

Traditionally, for fruits and vegetables quality assessment are determined by the physical characteristics such as colour, shape and firmness. In this research, an electronic nose will be used to determine the freshness state of tomatoes. And the electronic nose is a combination of three different types of gas sensor. The electronic nose detects the aroma produced by the tomatoes before analyzing it into its stage of ripeness. Then the electronic nose will then categorize it into three different states; fresh, slightly fresh and rotten based on the results obtained from the sensors. Before the experiments can be started, suitable types of sensors should be chosen and tested separately to ensure it is working well. By observing the output waveforms between normal conditions with a fresh fruits, it shows a slight change in terms of the voltage. Therefore it is safe to say that during the process of ripeness, the fruits actually produce gas and it is detected by the sensors. During the fresh condition and also rotten condition, we can also see the differences in terms of the voltage. One of the sensors, even during the rotten condition, the voltage across the load resistance increases. But for the other two sensors, during the fresh condition, the voltage it obtains increases however during the rotten condition, the voltage drops. Therefore, it is feasible to say that the electronic nose can detects whether the fruit is fresh or rotten by observing the changes in all three sensors.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Fruits are as valuable as other types of human foods, either eaten fresh or as jam, or even preserved. They are many types of fruits that are manufactured into other types of food like cookies, muffins, yoghurt and many more and fruits also are used to make beverages such as fruits juices or alcoholic beverages and even vinegar.

Due to various applications of the fruits, it's important to maintain the freshness of the fruits. Monitoring and controlling ripeness becomes an important issue in the fruit industry since the state of ripeness during harvesting; storage and market distribution determines the quality of the final product measured in terms of customer satisfaction [1].

1.2 Problem Statement

Although many methods of ripeness fruit monitoring has been proposed which depends on each fruit characteristics and the measurement objectives, an improvement for finding suitable algorithm to evaluate fruit ripeness is still needed [2]. Traditionally, the fruits quality is determined by the physical characteristics such as color, size and firmness without damaging the fruits.

The other way is to accurately measure the fruits quality is by measuring the starch, flesh texture, taste, fibers and its pH value but unfortunately this method of fruits quality measurement damages the fruits. For example, determining the freshness state of the fruits by the starch contents in the fruits, either it has turned into sugar. A rotted fruit but not bruised, with a drop of iodine on a slightly rotten part will turn a dark blue or black color if there is starch there. If it stays yellow, then most of the starch did turn into sugar. But the methods are not reliable if the amount of fruit needs to be checked is in a large amount and it would be time consuming. Therefore, the methods to test the fruits freshness have to be revised to ensure it is efficient.

Based on studies, after a fruit ripens, it would produce a gas known as Ethylene Gas (C_2H_4). An alternative strategy for determining the state of ripeness consists of sensing the aromatic volatiles emitted by fruit using electronic olfactory systems [1-6]. By using the multi-array of metal oxide sensors, it can detect the presence of the gas produced from the fruits before conditioning it and furthering it by classifying and determining the qualities of the fruits; fresh fruits or bad fruits using the neural network.

1.3 Objectives

- To test the sensors to ensure the sensor itself can operate in different temperature
- To test the circuit to ensure the circuit is able to perform and supports multiple arrays of sensor
- To collect and to analyze data based on the experiments conducted

1.4 Scope of Study

- To study the consistency of the waveform from the three sensors

1.5 Feasibility

Observing from the output waveforms that we have obtained from the experiments conducted, we can actually sees the differences between a fresh fruit and a rotten fruit. Therefore, this project is feasible to study and detect the quality of the fruits and vegetable.

1.6 Relevancy

This project is relevant to the food industry due to the variety usage of fruits as in canned foods, fruit manufactured, vinegar and beverages which needs the quality of the fruit to be qualified first before the manufacturing process can begins.

This project is also applicable to other type of applications that involves gas detection for example gas leak detection or hazardous gas detection.

CHAPTER 2

LITERATURE REVIEW

2.1 Fruit Ripening

Ripening is a natural process occurs in fruits, which actually caused them to be edible. Generally, a fruit becomes sweeter, less green, and softer as it ripens. However, the acidity as well as sweetness rises during ripening process, but the fruit still tastes sweeter. The reason for this is the Brix-Acid Ratio[7].

The organic compound involved with ripening is ethylene (C_2H_4), a gas created by plants from the amino acid methionine ($HO_2CCH(NH_2)CH_2CH_2SCH_3$). Ethylene increases the intracellular levels of certain enzymes in fruit and fresh-cut products, which include [8]:

- Amylase, which hydrolyzes starch to produce simple sugars, and
- Pectinase, which hydrolyzes pectin, a substance that keeps fruit hard.

Other enzymes break down the green pigment chlorophyll, which is represented by blue, yellow, or red pigments. Hormone levels in fruit are often connected to pollination (the transfers of pollen grains to the plant carpel of flowering plants, the structure that contains the ovule). If too few seeds in a multi-seeded fruit are formed, the flesh of the fruit may not develop in some areas and as a consequence ripening will be retarded or prevented. Fruit growers increasingly monitor seed ratios in developing and/or mature fruit and adjust pollination management accordingly.

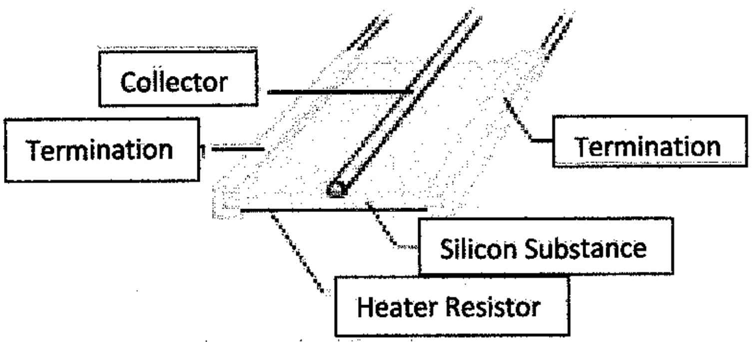


Figure 1: Chip-type sensor

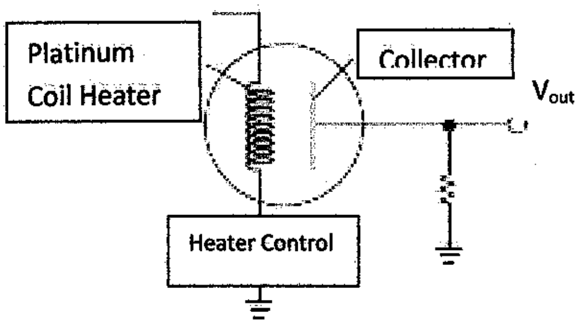


Figure 2: Bead-type sensor

Metal oxide semiconductor sensors are the most versatile of all sensors as they detect a wide variety of gases and its functionality is not limited to one or two applications.

2.3 Electronic Nose

Electronic noses are based on multi arrays of thin metal oxide sensor and suitable pattern recognition techniques. This approach implemented in different modules for each application [3]. Figure 3 shows the schematic diagram of the olfactory system [1].

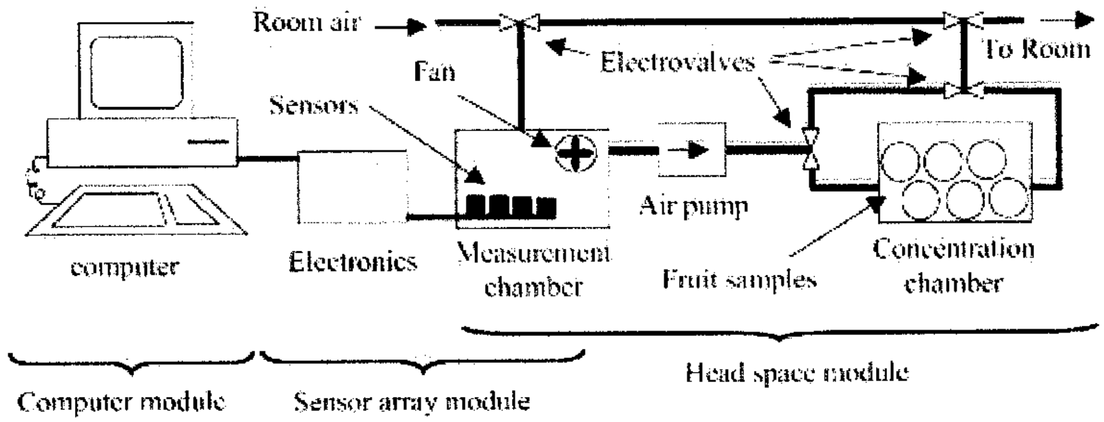


Figure 3: Schematic diagram of the olfactory system

The sensing material in gas sensors is metal oxide, typically SnO_2. The electrical resistance of sensor depending on the selected gas concentration though unfortunately, the sensitivity is affected by ambient temperature and humidity [2]. There are 3 different type sensors in sensor array used which is Alcohol, MQ-6 and TGS 2600.

Table 1: Sensor used in assessment system

Sensor	Applications
Alcohol	Alcohol checker, Breathalyzer
MQ-6	LPG, iso-butane, propane, LNG, avoid the noise of alcohol and cooking fumes and cigarette smoke
TGS 2600	Air cleaners, Ventilation control, Air quality monitor

2.4 Computer Interfacing

Interfacing means connecting an external device to a computer either for performing detection of an input or an output like keyboard, printer, sensing and data gathering, and adding external storage for the computer capacities [8]. To communicate between an external system with the computer, a device must be interface with the transmission system which is in this case; an array of gas sensors [9].

There are two methods of interfacing an external device to a computer. The first method is known as plug-and-play (PnP) or Universal Serial Bus (USB). It's a system build by the Microsoft with cooperation from Intel and many other hardware manufacturers. The main goal of PnP is to create a computer where the hardware and software can work together automatically to configure devices and assign resources, to allow for hardware changes and additions without the need for large-scale resource assignment alteration. In other words, the goal is to be able to just plug in a new device and immediately be able to use it, without complicated setup maneuvers [10].

The device is then connected through the Universal Serial Bus (USB) port. USB allows high-speed and easy connection of peripherals to a PC. When plugged in, everything configures automatically. The USB port is shown in figure 4.

Figure 4: USB port

The second method is using a microcontroller to connect between the hardware and computer [8]. In order to use this method, one should know how to program the microcontroller, having an Analog to Digital (A/D) converter and know communication ports configuration. Figure 5 shows the image of a microcontroller and its pin configuration.

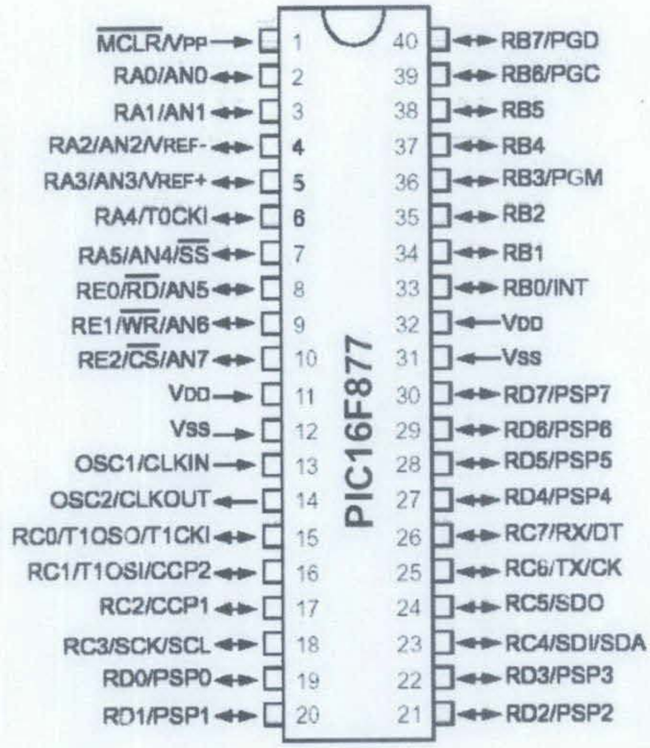


Figure 5: 16F877 microcontroller

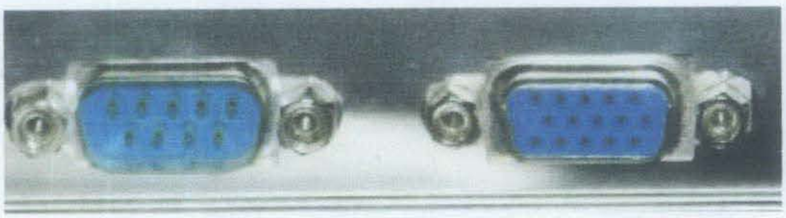


Figure 6: DB9 and DB15 Computer serial port

The computer serial port of a pc is shown in figure 6. Depending on which type and brand the user have for a computer, the number of pins used for the communication serial port is varied.

For example in the right side of figure 6, it is a 9 pin serial port and often referred as DB9 serial port. The "D" in DB9 stands for the shape of the serial port and the "B" is standardization for the entire communication serial port name and the number 9 is referred as the number of pins [11]. On the left side of figure 6, it is known as DB15 since it has 15 pins. Other than DB9 and DB15, there are also DB25 and DB50 used for the computer.

Even though the numbers of pin are different, but the function of the serial port remains the same despite the fact that they have different configuration settings for each other. The output from the microcontroller is then connected to the communication port by using the Recommended Standard 232 (RS232) cable. The example of a RS232 cable is shown in figure 7.

Figure 7: RS232 cable

CHAPTER 3
METHODOLOGY

3.1 Process Flow Chart

The process flow chart is shown in figure 8. Literature review and research are conducted during the first stage of the whole project. And that is including finding suitable research paper from Science Direct as a guidance and information related to the project for example like basic principles of electronic nose, sensors and etc.

For the second stage of the project, is to determine the type of sensors that are going to be used based on the sensors characteristics, functions, sensitivity and availability. Then the sensors would be tested separately to ensure it is working. If the sensor is not working, other sensor would be chosen to replace the malfunction sensor. Afterwards, the circuits which can hold all the three sensors is constructed before it is tested once again to ensure the circuit constructed can actually holds the three sensors together, else the sensor have to replaced.

The fifth stage of the project is to choose suitable method that can be used to interface between the computer and the sensors to get and record the readings. The next stage is to start collecting data's form the experiment conducted before the data can be analyzed.

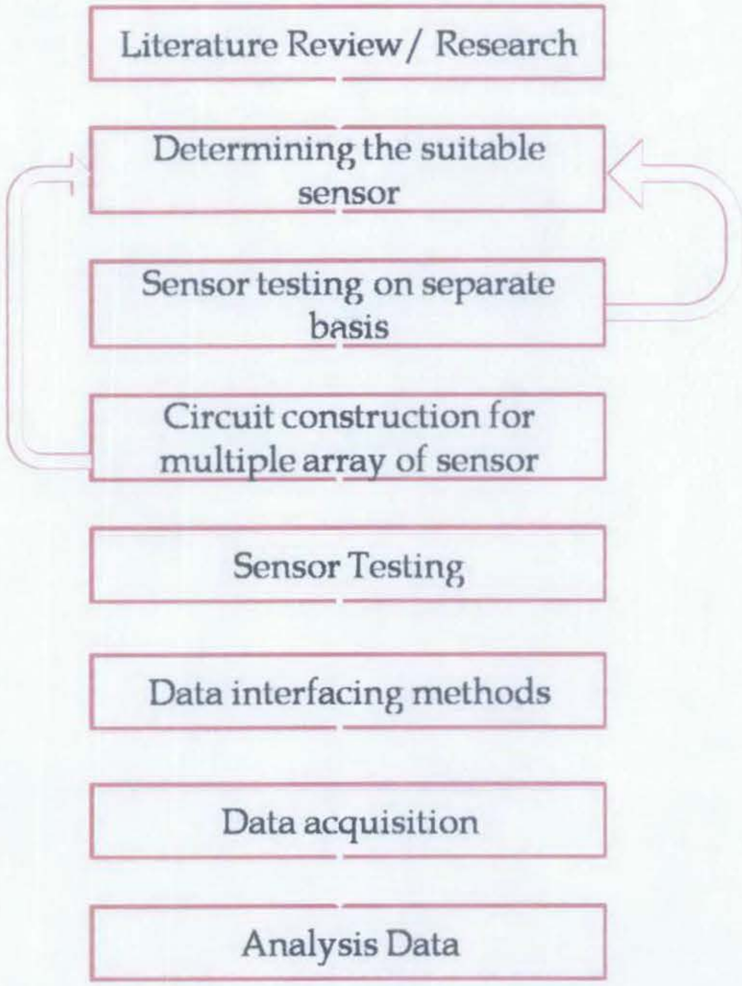


Figure 8: Scheme representing the methodology approach

3.2 Procedure Identification

In order to understands and perform effectively for this project, the problem statement and objectives should be defined first. The main objective of this project is to design a system or an artificial electronic nose which can detects the freshness of fruits and vegetables. Since this particular project title is divided into two different parts; hardware development and software development; this project would be mainly focusing on the hardware development. The objectives of hardware development would be designing the circuit that would be able to perform and handle multiple arrays of sensor and to collect data for the experiments conducted so that the data can be used for the software implementation.

3.3 Procedures

3.2.1 Definition : Search the information and data from the internet, journals and articles to further understand more on artificial nose

3.2.2 Research : Research has been conducted to choose the suitable sensor

3.2.3 Analysis : Testing all the sensors to check its sensitivity

3.2.4 Decision : Circuit construction for multiple arrays of sensors

3.4 Choosing Sensor

There are four sensors that were given during the first phase of the experiments. The first four sensors were MQ2, two MQ6 sensors and a MQ8 sensor. The functions of the sensor are shown in table 2.

Table 2: Types of Sensors

Sensor	Applications
MQ-2	LPG, i-butane, propane, methane, alcohol, hydrogen, smoke
MQ-8	Hydrogen, avoid the noise of alcohol and cooking fumes, LPG, CO
MQ-6	LPG, iso-butane, propane, LNG, avoid the noise of alcohol and cooking fumes and cigarette smoke

However, after testing the sensors separately, the sensors fail to perform as expected except for one MQ6 sensor. The graph of the fail output is shown in figure 9, 10 and 11. This failure to perform sensor is might caused by the sensor's old age. The contact within the sensor itself and the heater is not performing well after several years of being not used.

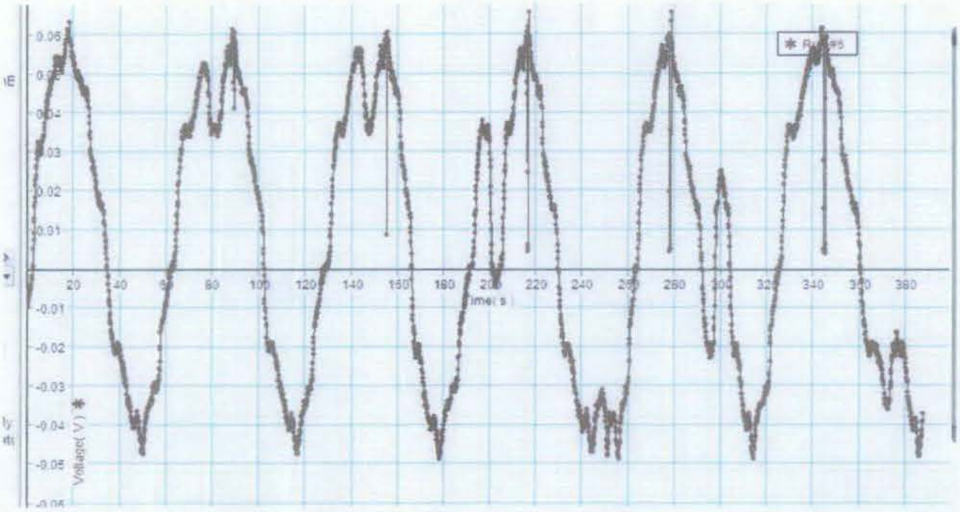


Figure 9: MQ2 sensor output

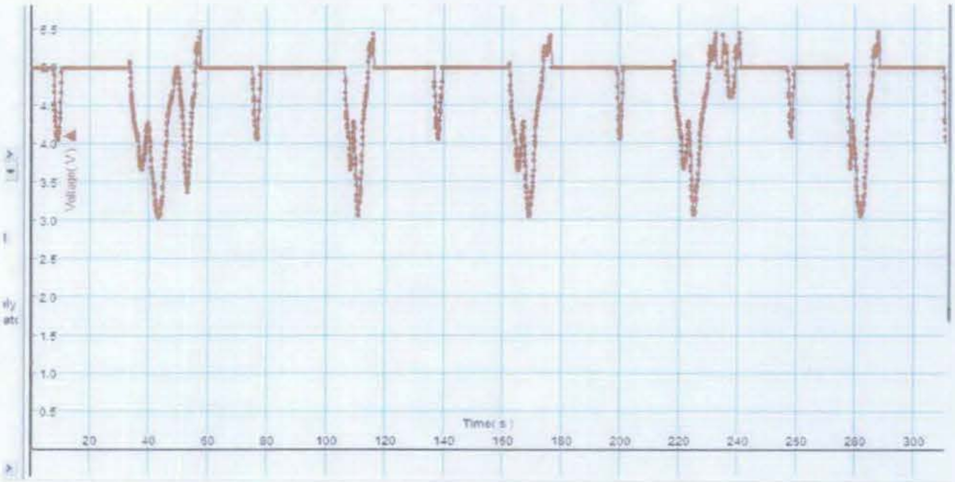


Figure 10: MQ6 sensor

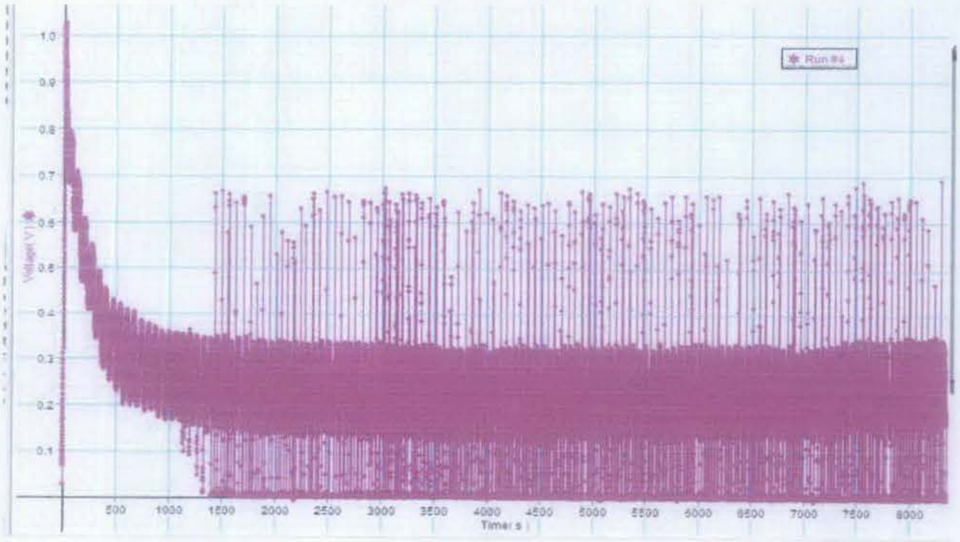


Figure 11: MQ8 sensor

Therefore, we have to buy new sensors online to replace the old sensors that were given to us in the first place. There are several types of gas sensors that were sold but due to application from the datasheet, we had chosen to use TGS 2600 and ALCOHOL sensor for the project.

Table 3: Types of Sensors

Sensor	Applications
Alcohol	Alcohol checker, Breathalyzer
TGS 2600	Air cleaners, Ventilation control, Air quality monitor

The functions of both sensors are described in table 3 and for figure 12, 13 and 14 shows the graph of a working sensor.

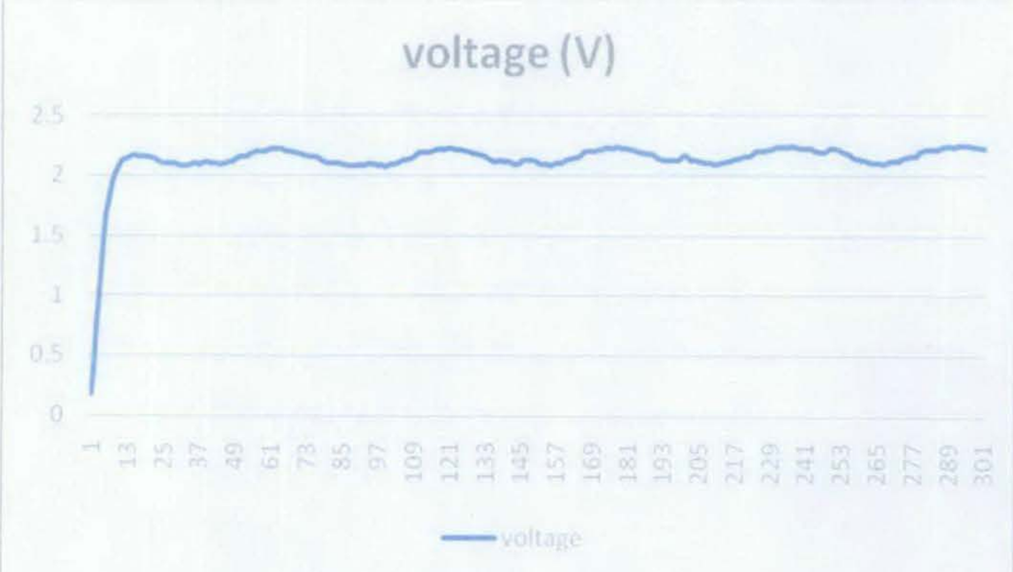


Figure 12: Working MQ6 sensor

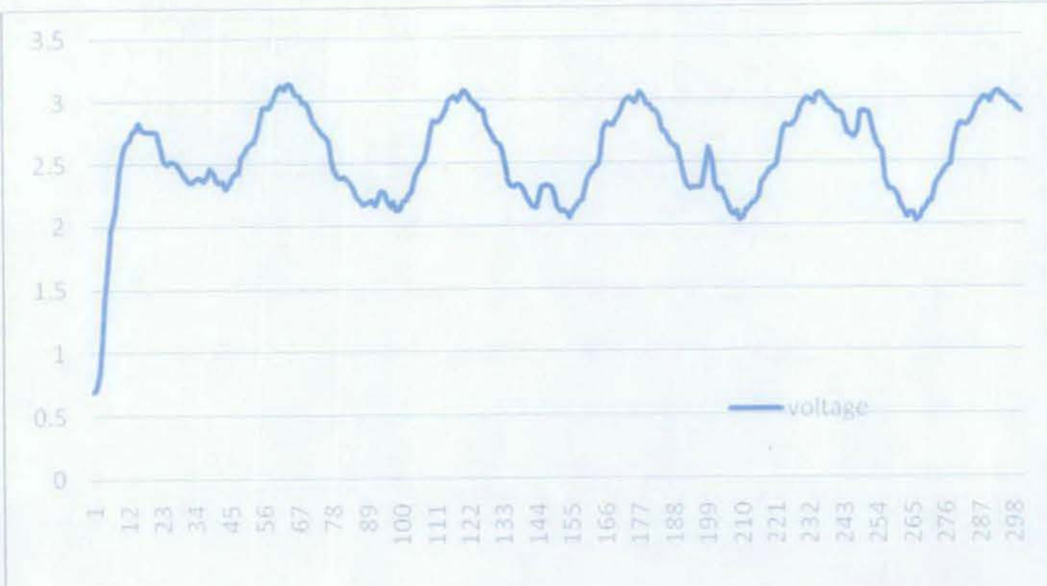


Figure 13: Alcohol sensor

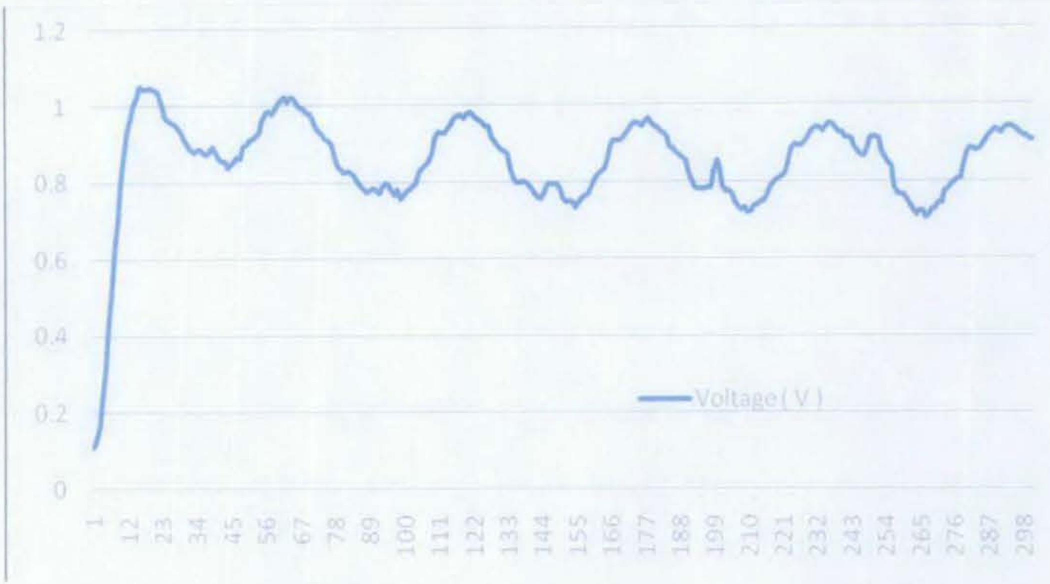


Figure 14: TGS sensor

3.5 Choosing The Interfacing Methods

As mention in the literature review part 2.4 for the computer interfacing methods, there are two separate methods of connecting the circuit to the computer which is using USB or microcontroller.

3.5.1 USB

To obtained raw data for the experiment, the tools used for the project is PASCO interface box. PASCO is a combination of hardware and software tools that can be do basic measurements as in voltage, temperature and currents using hardware which were connected to a computer through an USB port. Figure 15 shows the PASCO hardware.

Figure 15: PASCO hardware

To use the PASCO itself, the sensor plug is required to connect either into the digital or analog inputs at the PASCO interface box. To start collecting the data, at the Science Workshop program window, the START function s clicked. Then data can be monitored from the graph function or from the table function. The Science Workshop program window is shown in figure 16.

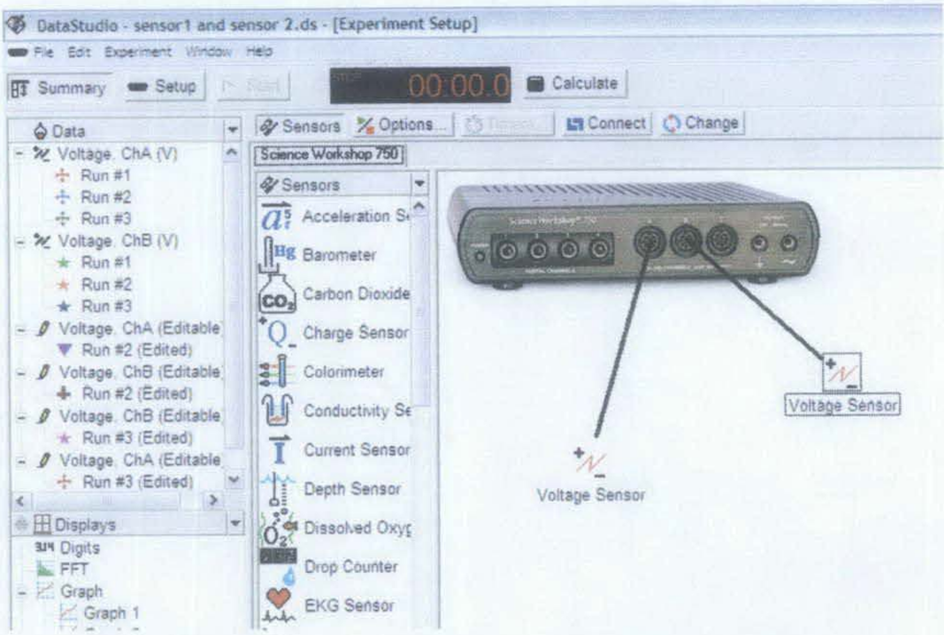


Figure 16: Science Workshop program window

Figure 17 shows the block diagram of the actual connection from the sensors to the PASCO interface and into the computer. The fruit is within an air tight chamber with the three sensors. When the supply voltage is supplied, the sensor will start working by detecting the gas produced by the fruits and the PASCO interface receives it and sends it to the computer.

The data obtained from the PASCO interface will be shown in the Science Workshop program window either in graph form, histogram or even tables depending on which program the user desires. Therefore, it is possible to move the data obtained from the Science Workshop into an excel program.

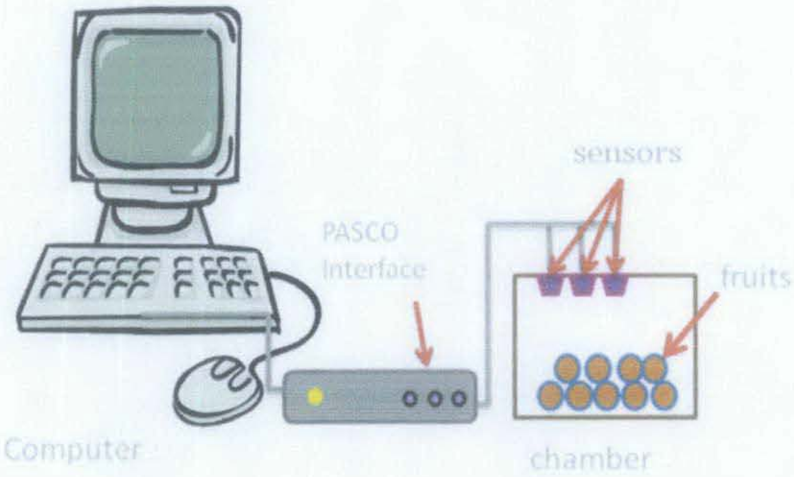


Figure 17: PASCO block diagram

3.5.2 Microcontroller

As mention in literature review part 2.4, the other method of interfacing the circuits to the computer is using a microcontroller. However, by using this method, one should know how to program a microcontroller either in C language or assembly language. Then know how to connect the microcontroller to the serial port to record the data.

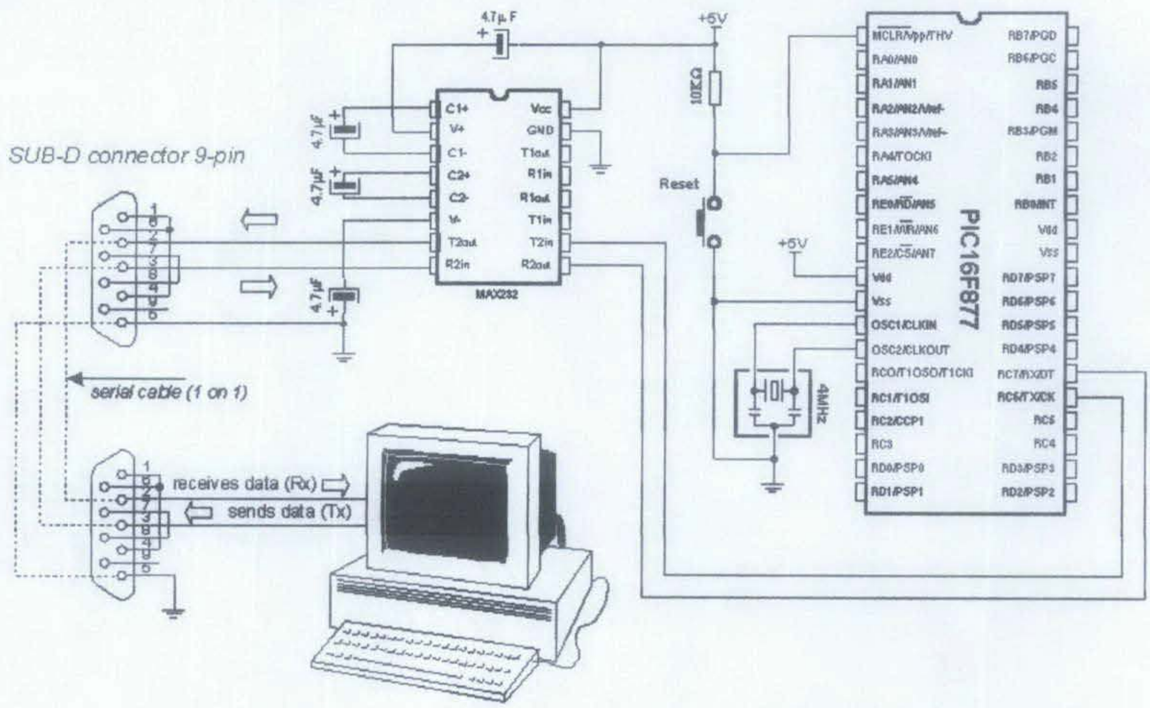


Figure 18: Block Diagram of Microcontroller Connection

In figure 18, it actually shows the connection from the microcontroller to the PC. There are several types of microcontroller in the market for example PIC 16F84, PIC 16F627, PIC 16F628, PIC 18F452 and etc. In figure 18, it uses PIC 16F877 where the PIC stands for Peripheral Interface Controller and the first two numbers stands for the microcontroller's series and the F877 shows the type of microcontroller.

To construct the circuit for the microcontroller connection, we should have two separate circuits where the first circuit holds the array of sensors and the second circuit holds the microcontroller and its components circuits.

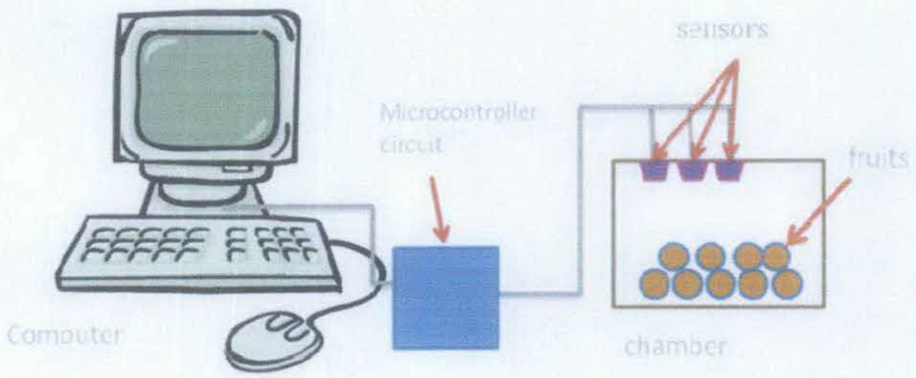


Figure 19: Microcontroller Block Diagram

Figure 19 shows the block diagram of the actual connection from the sensors to the microcontroller circuits and into the computer. The fruit is within an air tight chamber with the three sensors. When the supply voltage is supplied, the sensor will start working by detecting the gas produced by the fruits and the microcontroller circuits receives it, translates it into a digital data before sending it to the computer. The data obtained from the microcontroller will be recorded into an excel program depending on how the coding is written.

3.5.3 Methods Chosen

For the initial stage of the project, both interfacing methods are tested and proven to be useful. However, for the long time, it is more convenient to use the PASCO instead of the microcontroller.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Sensor testing

Based from the output waveforms that are obtained from part 4.1, the sensors that we decided to use is MQ6, TGS and Alcohol sensor. The test is conducted by combining all the three sensors into a circuit which can hold them together. The basic circuit is shown in figure 20. The internal circuits of each sensor are shown in appendix A and the data sheets for each sensor are attached in appendix B.

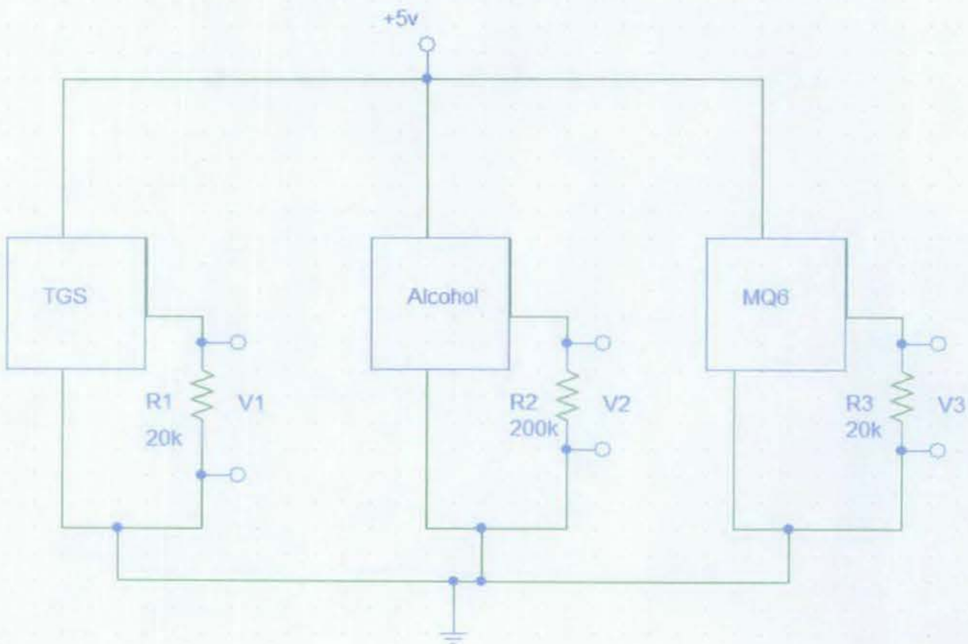


Figure 20: Basic circuit of the sensor

The actual diagram of the testing circuits is shown in figure 21 below. The power supply is connected to the circuit while the PASCO hardware connected to the load resistor within the sensor circuits and the computer.

Basically, one can see the sensor as a variable resistor where the value of the resistor can change depending on the input which is in this case is the gas that it detects. The reason on why we measured across the load resistance instead of across the resistor itself is because it is more reliable to measure across the load resistor and it will show larger value compare to measuring across the sensor itself. Hence, it will be easier to analyze the data.

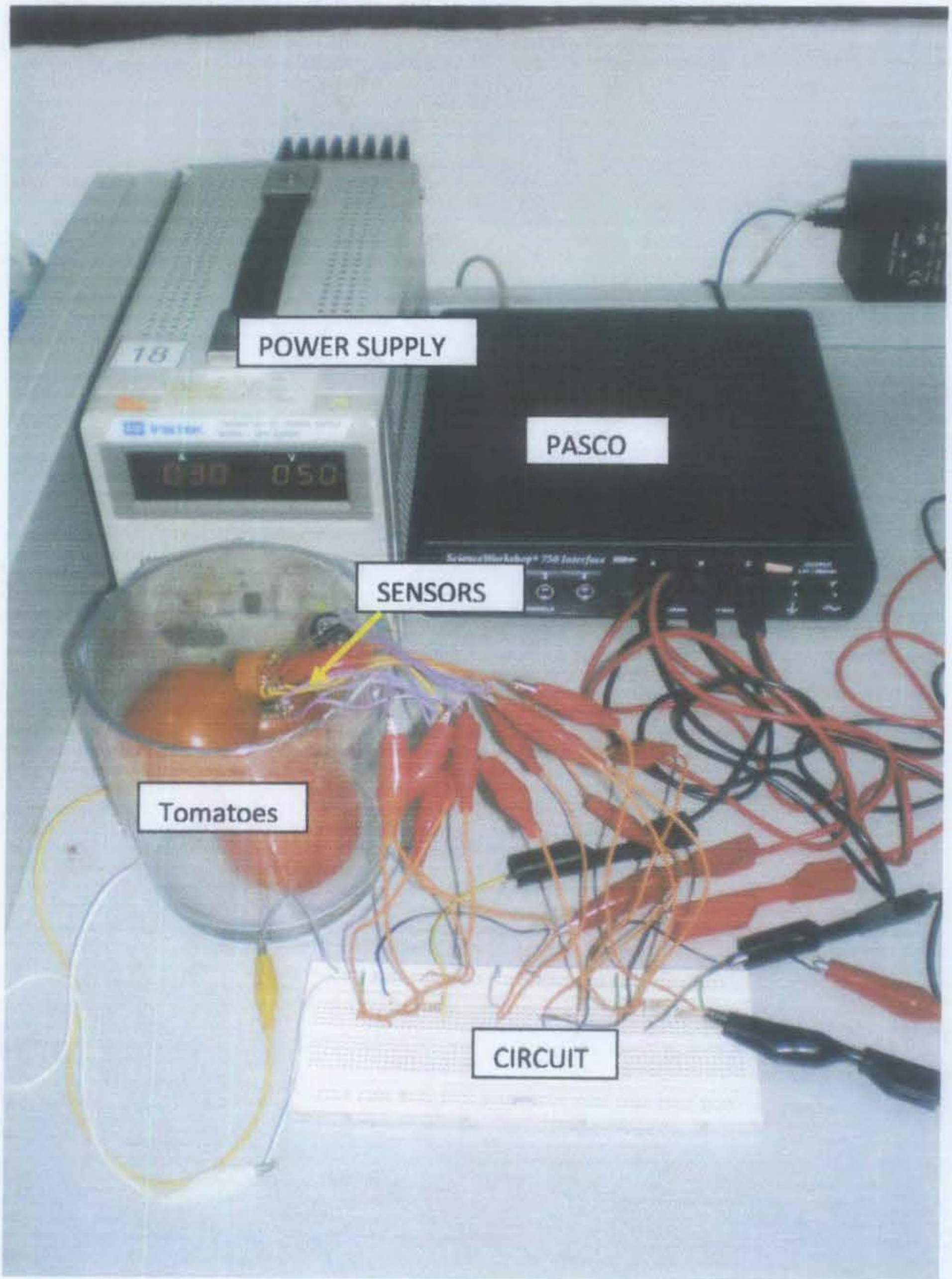


Figure 21: Sensor testing for the actual diagram

4.2 Results for Morning Data

The experiments is conducted several times a day and it has been pre-determined that the reading will only starts at day 1 until day 11. The tomatoes will rots on the 9th day, however the reading will still be taken as we want to see what would happens after it rots and what would it read afterwards. The data is shown in appendix C.

4.2.1 Initial Reading

Before the readings of the fruits can starts, the initial readings of the sensors voltage should be taken as a baseline of this project. Figure 22 shows the graph obtained from all the three sensors.

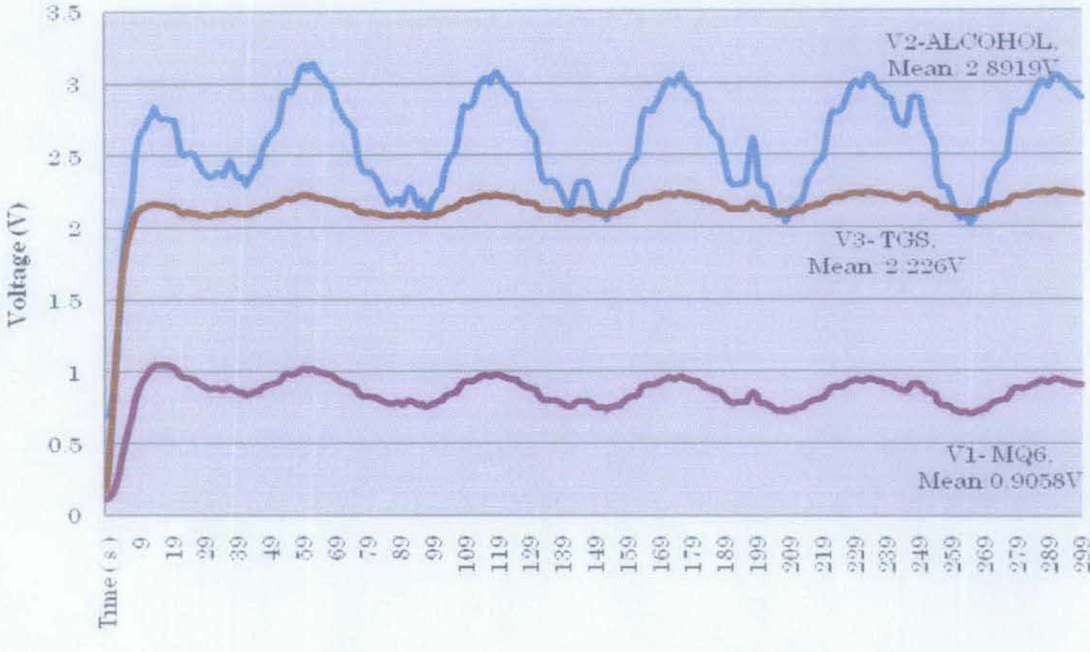


Figure 22: The initial readings from all three sensors

Based on the figure 22, during the first 40s the sensor's waveform hasn't yet stabilized. This is because the sensor is still heating and it usually took several seconds before it can actually reads and measure the signals.

Therefore, for the experiment, the data collection time had to pre-determine and it will be based on the average value that we get from a certain time to ensure all the data are standardized.

From the graph obtained, the mean values for all three sensors are taken. For TGS sensor, the mean value is 2.226V, alcohol sensor is 2.8919V and MQ6 sensor is 0.9058V. The values are stated in table 4 below.

Table 4: Mean Value for all three sensors

Type sensor/ Reading	Mean Value(V)
TGS sensor	2.226
ALCOHOL sensor	2.8919
MQ6 sensor	0.9058

4.2.2 Day1 data

For day 1 and for the rest of the day, the data will be taken between the 300s and 700s. In figure 23 below, it shows the waveform obtained from the 3 sensors by using a fresh tomato as a sample.

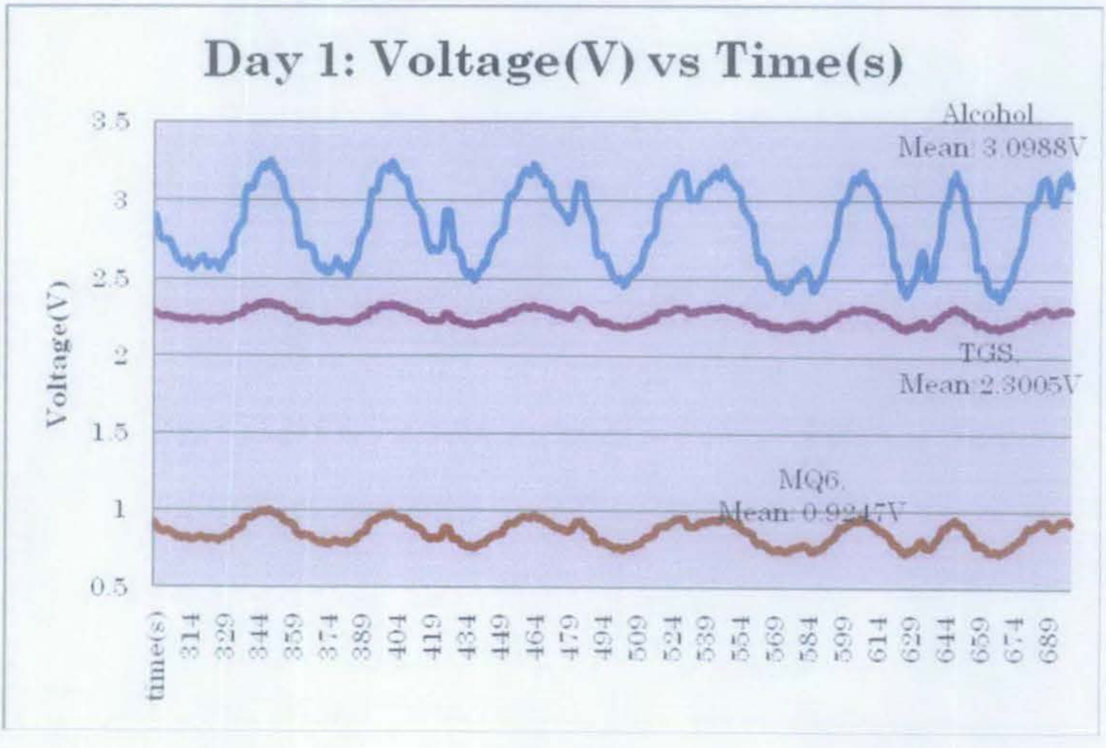


Figure 23: Day 1 data values

For day 1 reading, the TGS sensor mean value is 2.3005V, Alcohol sensor is 3.0988V and MQ6 sensor is 0.9247V. The values are simplified in table 5.

Table 5: The data between initial reading and day 1

Type sensor/ reading	Initial Readings (V)	Day 1 (V)
TGS sensor	2.226	2.3005
Alcohol Sensor	2.8919	3.0988
MQ6 sensor	0.9058	0.9247

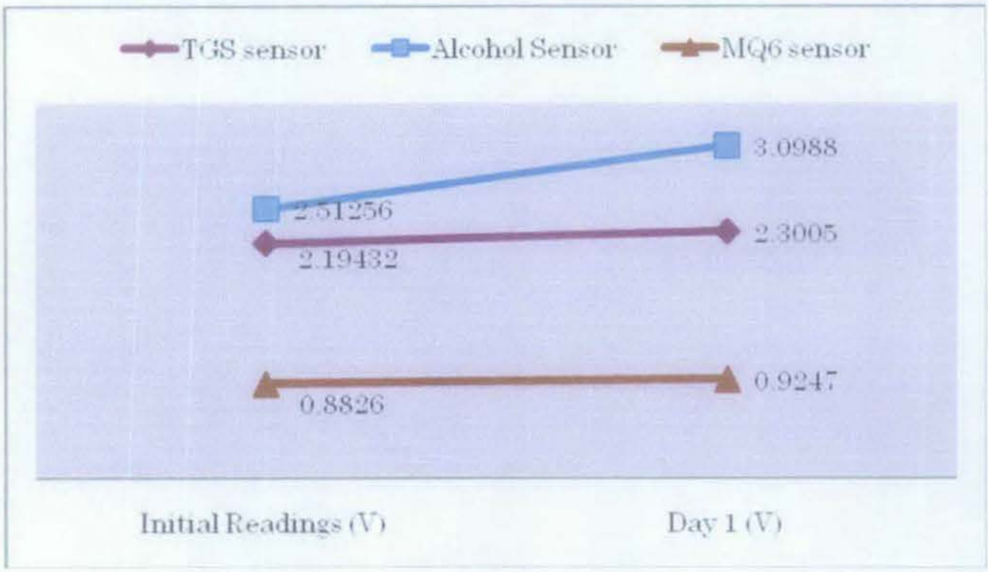


Figure 24: The graph scatter for initial reading and day 1

Observing from table 4 and figure 24, there is a difference between day 1 and the initial readings. For TGS sensor, it increases around 0.0405V while for Alcohol sensor, it increases around 0.2069V and for MQ6 sensor, and it increases around 0.0189V.

Therefore, it is safe to say that the fruits are actually producing gas and the three sensors are actually sensing it.

4.2.3 Day 3 data

The data shown in figure 25 is the data obtained from day 3. Day3 is chosen to analyzed instead of day2 is because day3 has been set as the last day of still fresh condition. For day 3 data, the output waveform is shown as in figure 25.

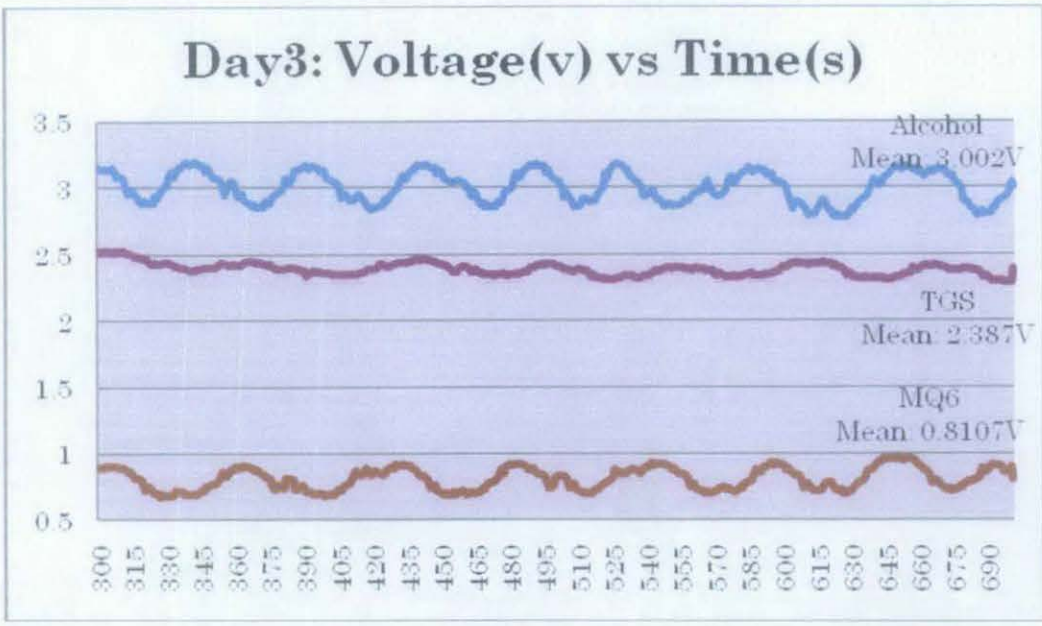


Figure 25: Day 3 data values

From figure 25, the TGS value obtained is 2.387V while Alcohol is 3.002V and MQ6 is 0.8107V. In table 6 below, the data between day 1 and day 3 are compared.

Table 6: The data between day 1 and day 3

	Day1	Day3
TGS sensor	2.3005	2.387
Alcohol sensor	3.0988	3.002
MQ6 sensor	0.9247	0.811

From table 6, the differences between day 1 reading and day 3 readings can be calculated. For TGS sensor, the reading increased around 0.0865V which is from

2.3005V into 2.387V. For Alcohol sensor, the reading decreases around 0.0986V from day1 to day 3 while for MQ6 sensor, the reading for day 1 is 0.9247V and day3 is 0.811V. The differences between both days are 0.1137V. The decrements for both alcohol and MQ6 sensor can be caused by a lot of external factors for example unstable connection between the sensor and the output probe.

4.2.4 Day 4 data

Day 4 is chosen as the first day for when the tomato has entered the intermediate state of freshness. The output waveform is shown in figure 26.

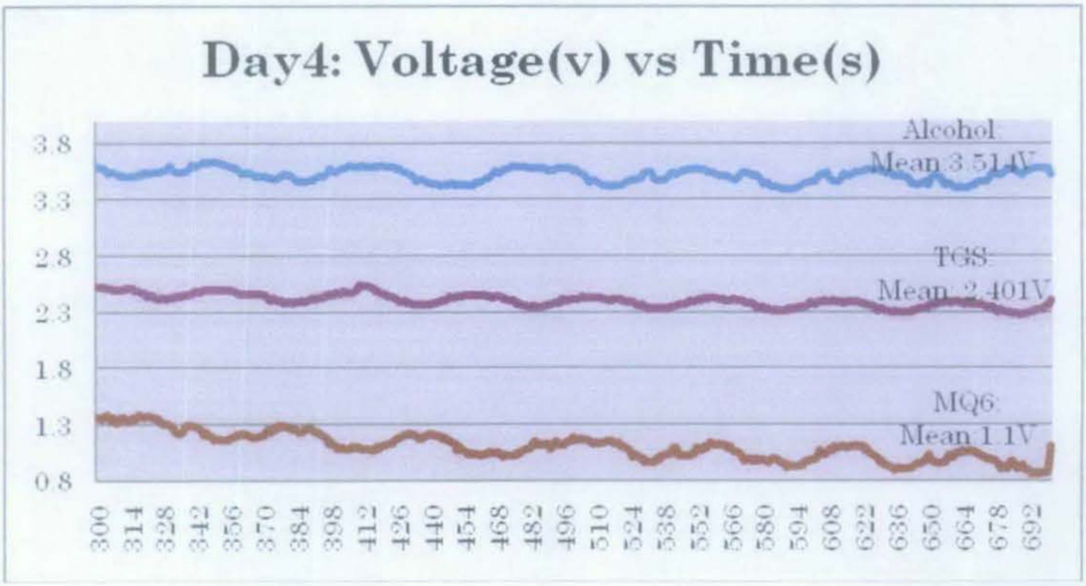


Figure 26: Day 4 data values

From figure 26, the TGS value obtained is 2.401V while Alcohol is 3.514V and MQ6 is 1.1V. In table 7 below, the data between day 1, day 3 and day 4 are compared.

Table 7: The data between day 1, day 3 and day 4

	Day1	Day3	Day4
TGS sensor	2.3005	2.387	2.401
Alcohol sensor	3.0988	3.002	3.514

MQ6 sensor	0.9247	0.811	1.1

From table 7, for the TGS sensor, the reading increased around 0.014V from day 3 to day 4. For Alcohol sensor, the reading increases around 0.512V from day 4 to day 3 while for MQ6 sensor, the reading for day 4 increased 0.289V from day3.

4.2.5 Day 8 data

For day 8, the tomato has reached it last day before it started to rots. Therefore, day 8 is chosen as the last period of the intermediate freshness stage. The output waveform is shown in figure 27.

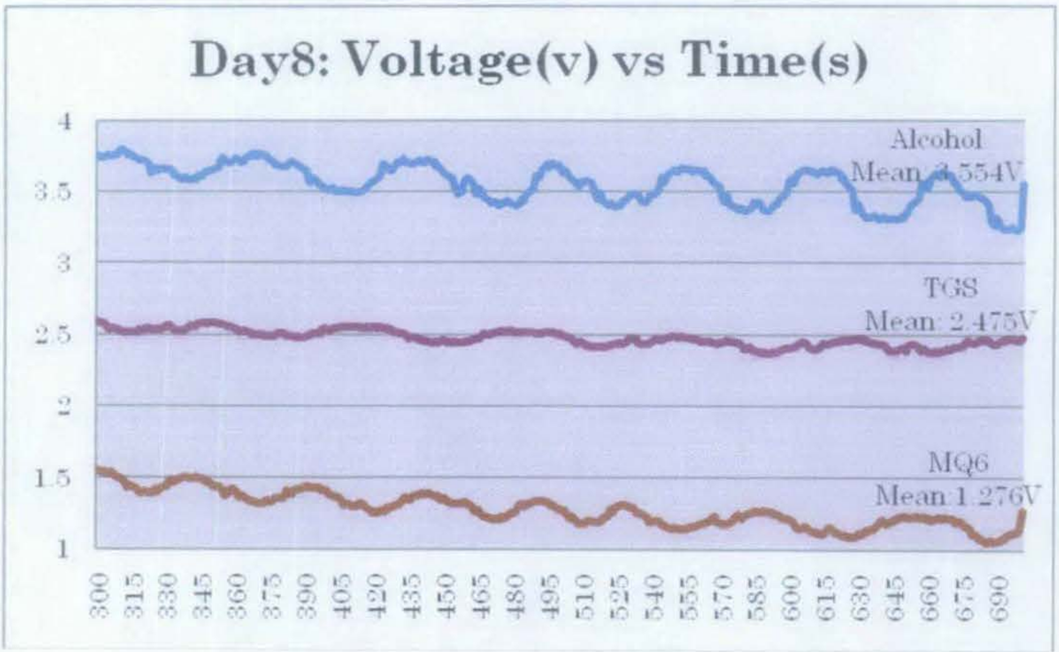


Figure 27: Day8 data values

From figure 27, TGS sensor value obtained is 2.475V while alcohol sensor value obtained is 3.544V and MQ6 sensor value is 1.276V. In table 8, the data is compared between day 1, day 3 and day 8.

Table 8: The data between day 1, day 3, day 4 and day 8

	Day1	Day3	Day4	Day8
TGS sensor	2.3005	2.387	2.401	2.475
Alcohol sensor	3.0988	3.002	3.514	3.554
MQ6 sensor	0.9247	0.811	1.1	1.276

From table 8, the differences between day 1, day 3, day 4 and day 8 can be observed. For TGS sensor, the reading increased around 0.074V from the day4 to day8. For Alcohol sensor, the voltage increases around 0.04V from the day4 to day8. For MQ6 sensor, the reading increases from 0.176V from day 4 to day 8.

4.2.6 Day 9 data

Day 9 is the day where the tomato started to rots. The output waveform is shown in figure 28.

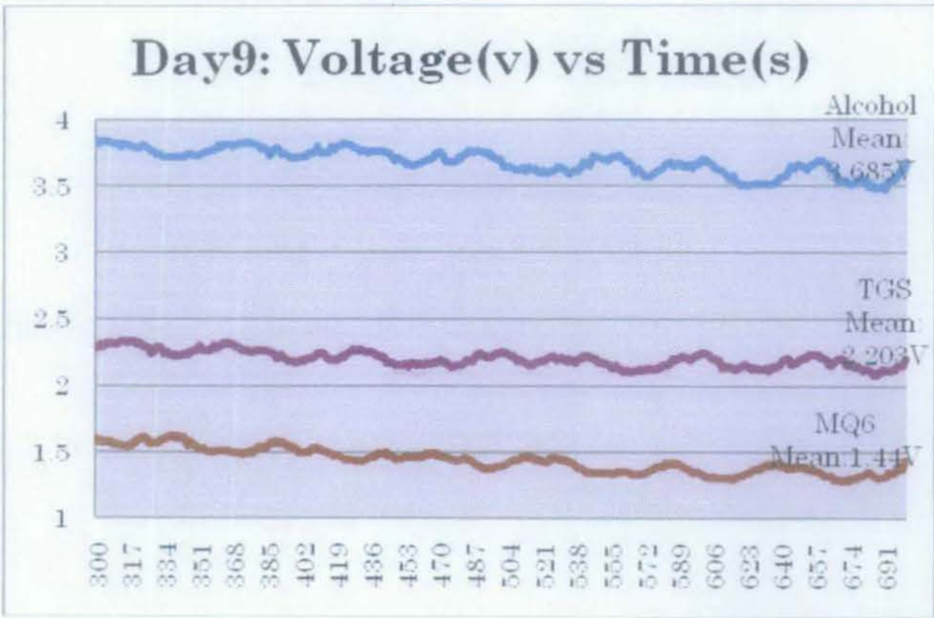


Figure 28: Day9 data values

From figure 28, the reading of day 9 for TGS sensor is 2.203V while for Alcohol sensor is 3.685V and for MQ6 sensor, the reading is 1.44V. In table 9 below, the comparison between the readings of day 1, day 3, day 4, day 8 and day 9 is shown.

Table 9: The data between day 1, day 3,day 4, day 8 and day 9

	Day1	Day3	Day4	Day8	Day9
TGS sensor	2.3005	2.387	2.401	2.475	2.203
Alcohol sensor	3.0988	3.002	3.514	3.554	3.685
MQ6 sensor	0.9247	0.811	1.1	1.276	1.44

From table 9, the differences between day 1, day 3, day 4, day 8 and day 9 can be observed. For TGS sensor, the reading decreased around 0.272V from the day8 to day9. For Alcohol sensor, the voltage increases 0.131V from day 8 to day 9 while for MQ6 sensor, it actually increases for 0.164V from day 8 to day 9.

4.2.7 Day 10 data

Day 10 is taken to see the differences between the rotten and the fresh tomato. The data that has been taken on day 10 is shown in figure 29.

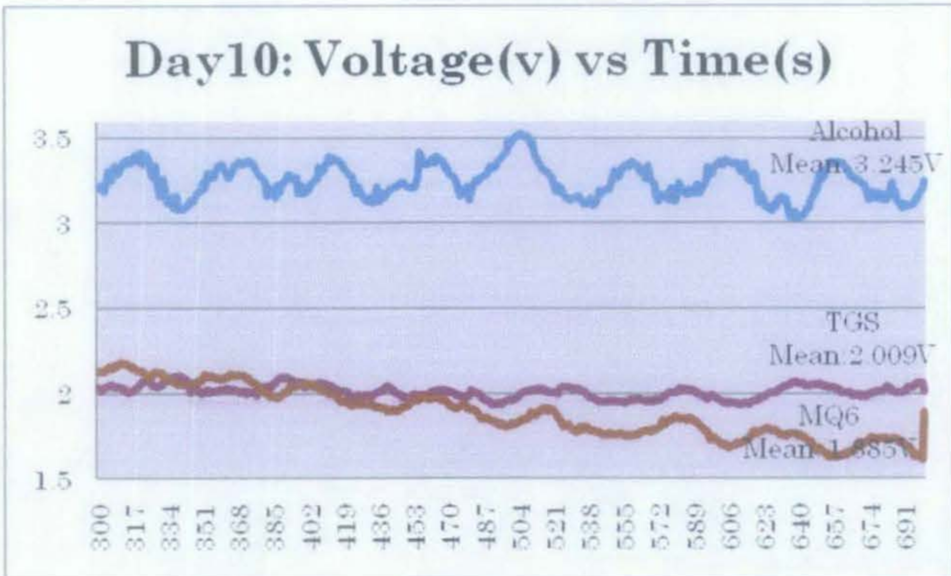


Figure 29: Day 10 data values

From figure 29, the reading of day 10 for TGS sensor is 2.009V while for Alcohol sensor is 3.245V and for MQ6 sensor, the reading is 1.801V. In table 10, the comparison between the readings of day1, day3, day8, day9 and day10 is shown.

Table 10: The data between day 1, day 3, day 4, day 8, day 9 and day 10

	Day1	Day3	Day4	Day8	Day9	Day10
TGS sensor	2.3005	2.387	2.401	2.475	2.203	2.009
Alcohol sensor	3.0988	3.002	3.514	3.554	3.685	3.245
MQ6 sensor	0.9247	0.811	1.1	1.276	1.44	1.801

From table 10, the differences between day 1, day 3, day 8, day 9 and day 10 can be observed. For TGS sensor, the reading decreased around 0.194V from the day10 to day9. For Alcohol sensor, the voltage decreases 0.44V from day 10 to day 9 while for MQ6 sensor, it actually increases for 0.361V from day 10 to day 9.

4.2.8 Day 11 data

Day 11 is set as the last day of the rotten days. Even though it can goes longer than day 11, but in this experiment, it has been determined that day 11 would be the maximum day. The data which has been taken on day 11 is shown in figure 30.

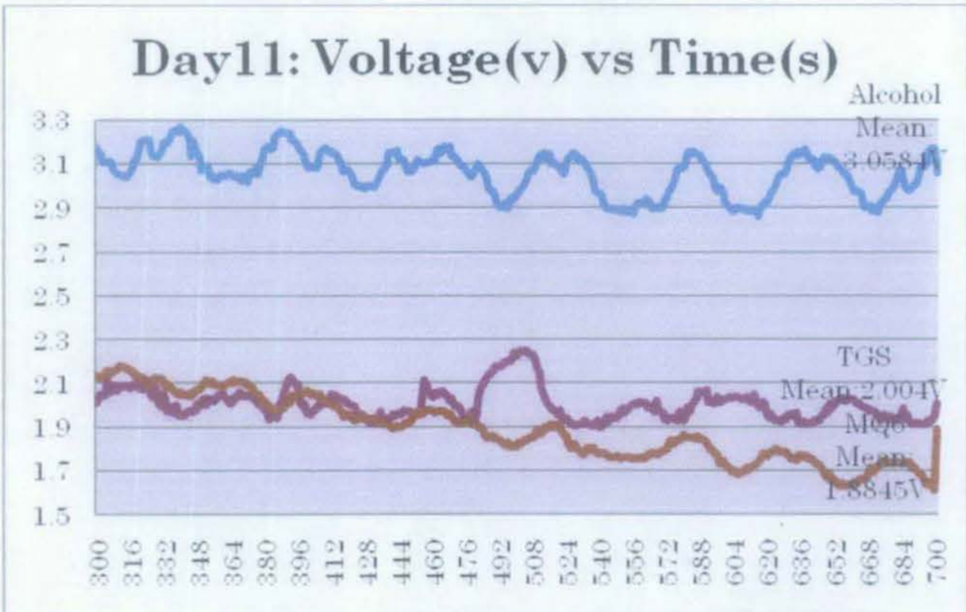


Figure 30: Day 11 data values

From figure 30, the reading of day 9 for TGS sensor is 2.004V while for Alcohol sensor is 3.058V and for MQ6 sensor, the reading is 1.885V. In table 11 below, the comparison between the readings of day1, day3, day8, day9, day 10 and day11 is shown.

Table 11: The data between day 1, day 3, day 4, day 8, day 9, day 10 and day 11

	Day1	Day3	Day4	Day8	Day9	Day10	Day11
TGS sensor	2.3005	2.387	2.401	2.475	2.203	2.009	2.004
Alcohol sensor	3.0988	3.002	3.514	3.554	3.685	3.245	3.058
MQ6 sensor	0.9247	0.811	1.1	1.276	1.44	1.801	1.885

From table 11 above, the differences between day 1, day 3, day 8, day 9, day 10 and day 11 can be observed. For TGS sensor, the reading decreased around 0.005V from the day11 to day10. For Alcohol sensor, the voltage decreases 0.187V from day 11 to day 10 while for MQ6 sensor, it actually increases for 0.084V from day 11 to day 10.

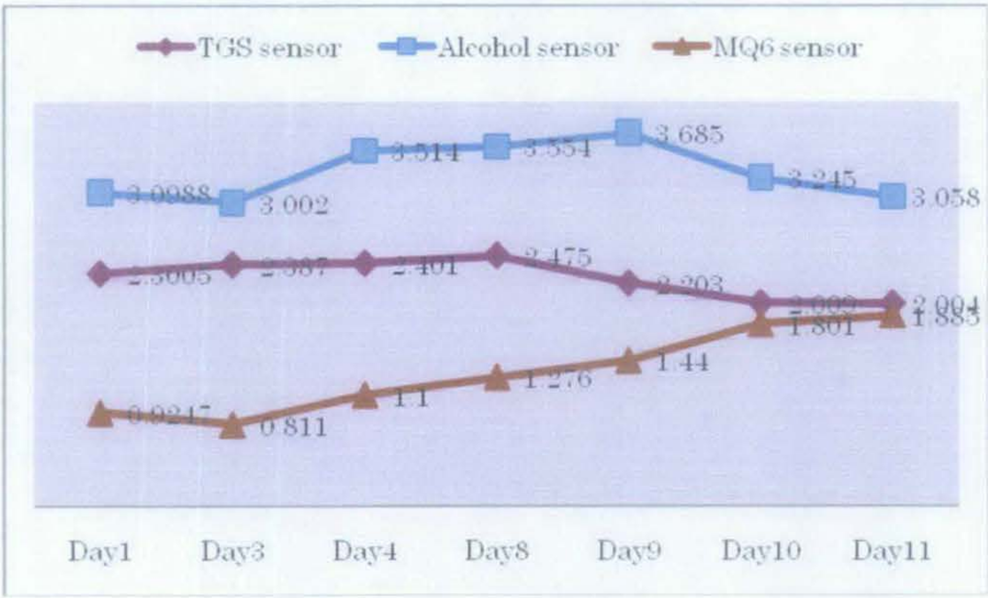


Figure 31: The graph between day 1, day3, day 8, day 9, day 10 and day 11

From all the data that has been collected and gathered shown in figure 31, during the fresh state to rotten state, the voltage of the sensor is kept increasing from day 1 to day 8. When the tomato has reach its rotten state as shown from day 9 to day 11, the voltage of TGS sensor and alcohol sensor starts to decreased but the voltage of MQ6 sensor keep increasing.

From the table also, it is shown that the data for still fresh condition for TGS is around 2.3005V to 2.475V and for the rotten state, the value is from 2.203V to 2.004V. The values for the still fresh condition increased around 0.1745V while during the rotten condition, the value decreases up to 0.199V. For Alcohol sensor, during the still fresh condition, the value is from 3.0988V to 3.554V while during the rotten condition is from 3.685V to 3.058V. The value of still fresh condition increased around 0.4552V while for the rotten condition, the values decreases up to 0.627V.

For MQ6 sensor, the voltage for the still fresh condition varied from 0.9247V to 1.276V but for the rotten condition, the values varied from 1.44V to 1.885V. The value of still fresh condition increased from 0.3513V while for rotten condition, the values increased up to 0.445V.

4.3 Afternoon Data

The data of the experiment below is taken separately during the afternoon from day 1 until day 11. The tomatoes will rots on the 9th day, however the reading will still be taken as we want to see what would happens after it rots and what would it read afterwards. The data is shown in appendix C.

4.3.1 Day1 data

For day 1 and for the rest of the day, the data will be taken between the 300s and 700s. In figure 32 below, it shows the waveform obtained from the 3 sensors by using a fresh tomato as a sample.

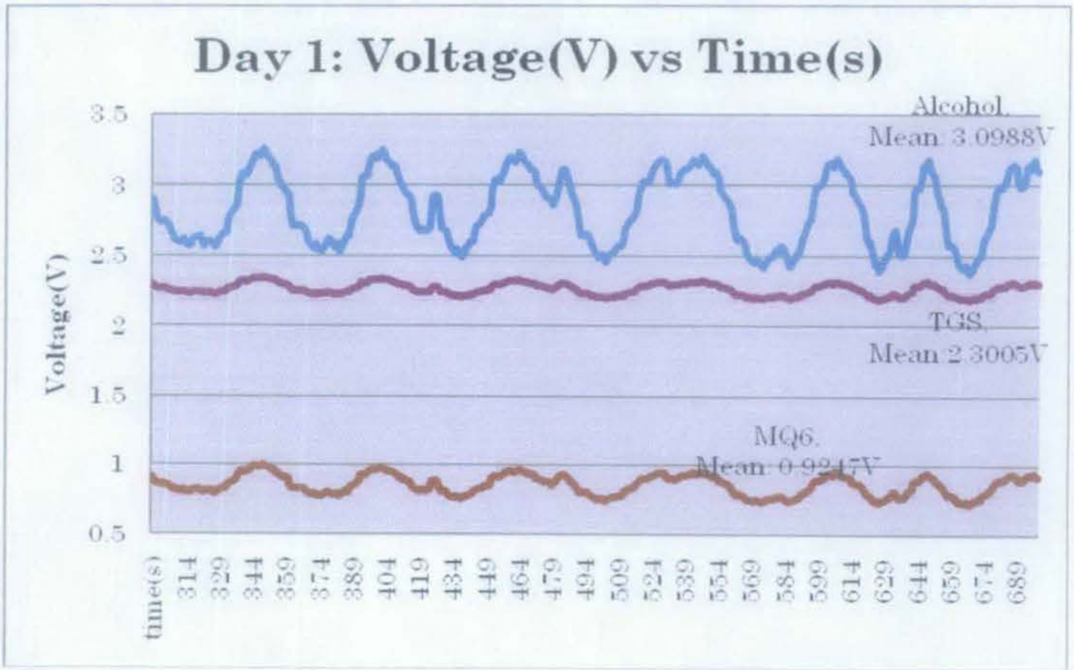


Figure 32: Day 1 data values

For day 1 reading, the TGS sensor mean value is 2.3005V, Alcohol sensor is 3.0988V and MQ6 sensor is 0.9247V. The values are simplified in table 12.

Table 12: The data between initial reading and day 1

Type sensor/ reading	Initial Readings (V)	Day 1 (V)
TGS sensor	2.226	2.3005
Alcohol Sensor	2.8919	3.0988
MQ6 sensor	0.9058	0.9247

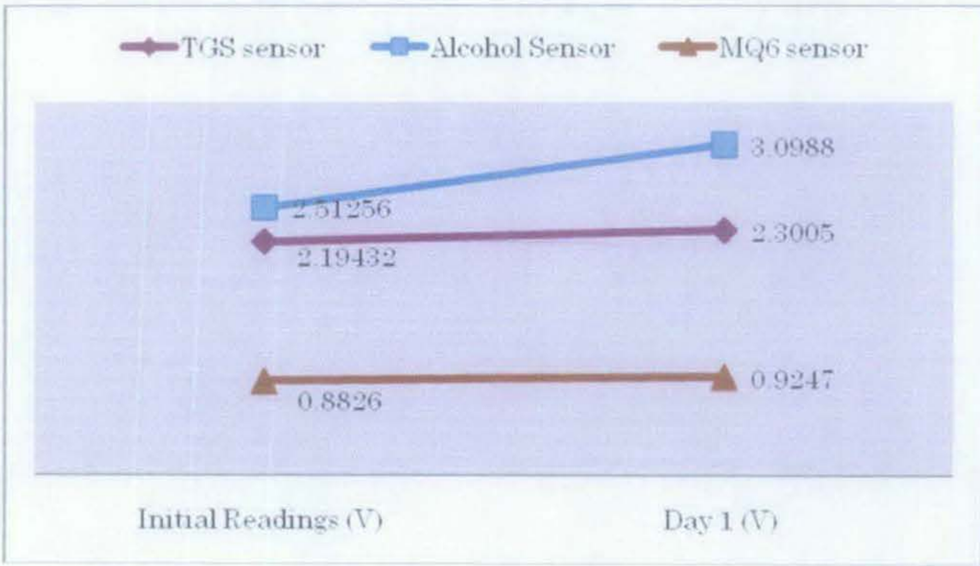


Figure 33: The graph scatter for initial reading and day 1

Observing from table 12 and figure 33, there is a difference between day 1 and the initial readings. For TGS sensor, it increases around 0.0405V while for Alcohol sensor, it increases around 0.2069V and for MQ6 sensor, and it increases around 0.0189V.

Therefore, it is safe to say that the fruits are actually producing gas and the three sensors are actually sensing it.

4.3.2 Day 3 data

The data shown in figure 34 is the data obtained from day 3. Day3 is chosen to analyzed instead of day2 is because day3 has been set as the last day of still fresh condition. For day 3 data, the output waveform is shown as in figure 34.

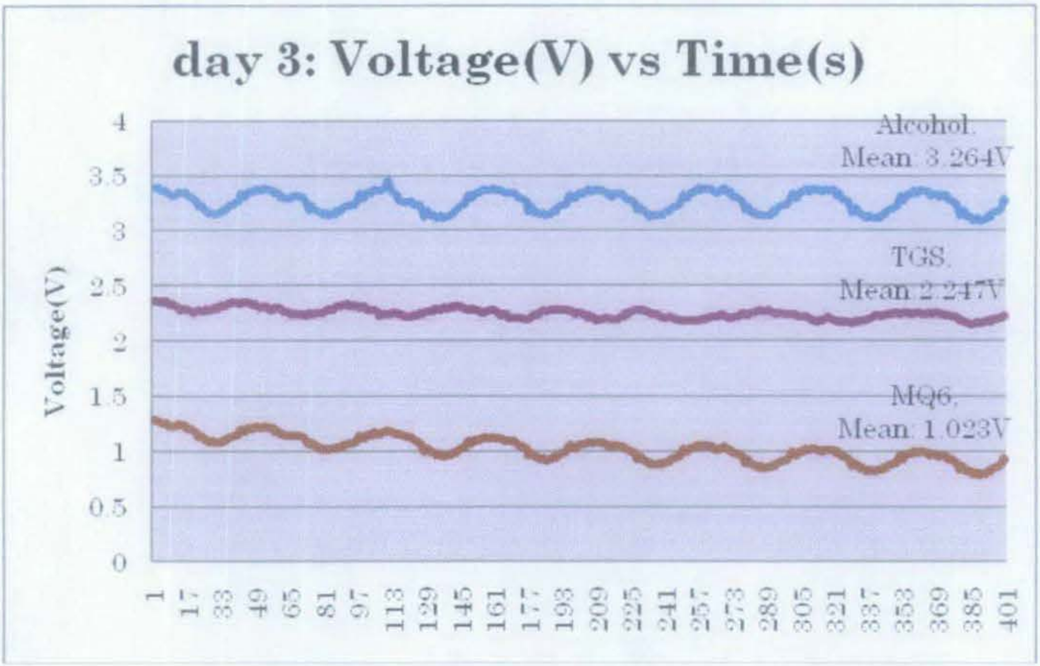


Figure 34: Day 3 data values

From figure 34, the TGS value obtained is 2.247V while Alcohol is 3.264V and MQ6 is 1.023V. In table 12 below, the data between day 1 and day 3 are compared.

Table 12: The data between day 1 and day 3

Type sensor/ reading	Day1 (V)	Day 3 (V)
TGS sensor	2.3005	2.247
Alcohol Sensor	3.0988	3.264
MQ6 sensor	0.9247	1.023

From table 12, the differences between day 1 reading and day 3 readings can be calculated. For TGS sensor, the reading decreased around 0.0535V which is from

2.3005V into 2.247V. The voltage dropped can be caused by a lot of external factors for example unstable connection between the sensor and the output probe.

For Alcohol sensor, the reading increases around 0.1652V from day1 to day 3 while for MQ6 sensor, the reading for day 1 is 0.9247V and day3 is 1.023V. The differences between both days are 0.0983V.

4.3.3 Day 4 data

Day 4 is chosen as the first day for when the tomato has entered the intermediate state of freshness. The output waveform is shown in figure 35.

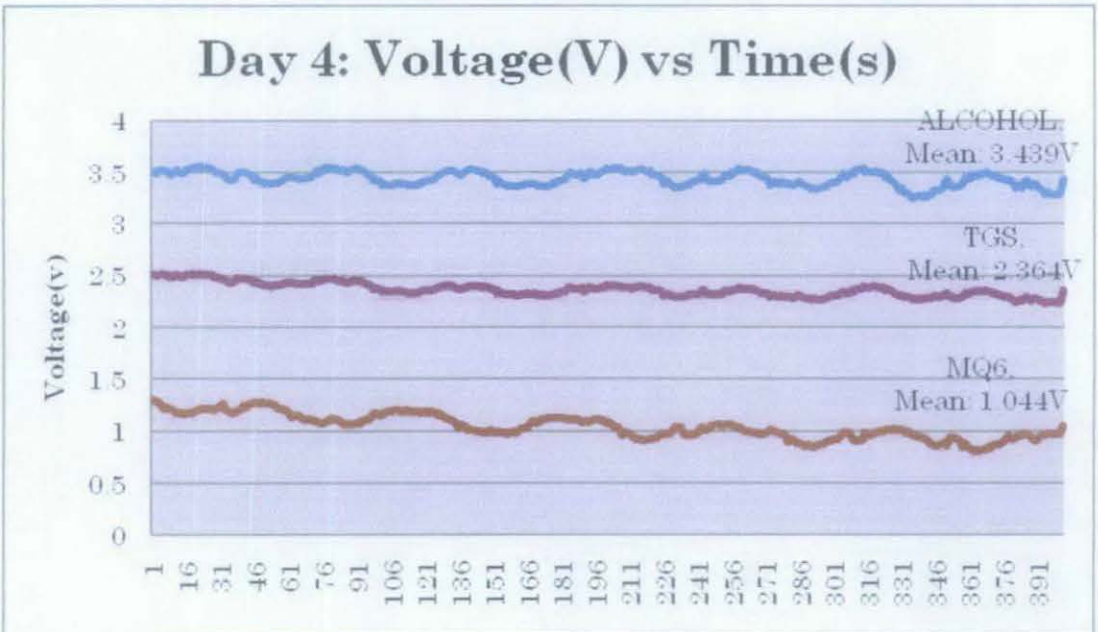


Figure 35: Day 4 data values

From figure 26, the TGS value obtained is 2.364V while Alcohol is 3.439V and MQ6 is 1.044V. In table 13 below, the data between day 1, day 3 and day 4 are compared.

Table 13: The data between day 1, day 3 and day 4

Type sensor/ reading	Day1 (V)	Day 3 (V)	Day4 (V)

TGS sensor	2.3005	2.247	2.364
Alcohol Sensor	3.0988	3.264	3.439
MQ6 sensor	0.9247	1.023	1.044

From table 13, for the TGS sensor, the reading increased around 0.175V from day 3 to day 4. For Alcohol sensor, the reading increases around 0.117V from day 4 to day 3 while for MQ6 sensor, the reading for day 4 increased 0.021V from day3.

4.3.4 Day 8 data

For day 8, the tomato has reached it last day before it started to rots. Therefore, day 8 is chosen as the last period of the intermediate freshness stage. The output waveform is shown in figure 36.

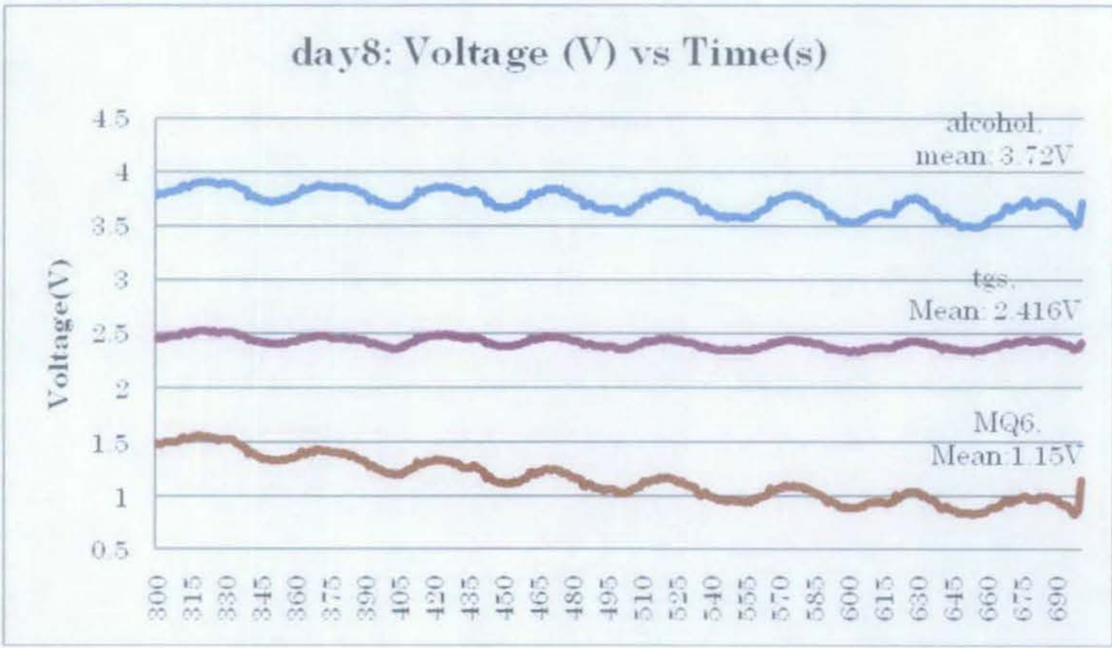


Figure 36: Day8 data values

From figure 36, TGS sensor value obtained is 2.416V while alcohol sensor value obtained is 3.72V and MQ6 sensor value is 1.15V. In table 14, the data is compared between day 1, day 3 and day 8.

Table 14: The data between day 1, day 3, day 4 and day 8

Type sensor/ reading	Day1 (V)	Day 3 (V)	Day4 (V)	Day 8 (V)
TGS sensor	2.3005	2.247	2.364	2.416
Alcohol Sensor	3.0988	3.264	3.439	3.72
MQ6 sensor	0.9247	1.023	1.044	1.15

From table 14, the differences between day 1, day 3, day 4 and day 8 can be observed. For TGS sensor, the reading increased around 0.052V from the day4 to day8. For Alcohol sensor, the voltage increases around 0.281V from the day4 to day8. For MQ6 sensor, the reading increases from 0.106V from day 4 to day 8.

4.3.5 Day 9 data

Day 9 is the day where the tomato started to rots. The output waveform is shown in figure 37.

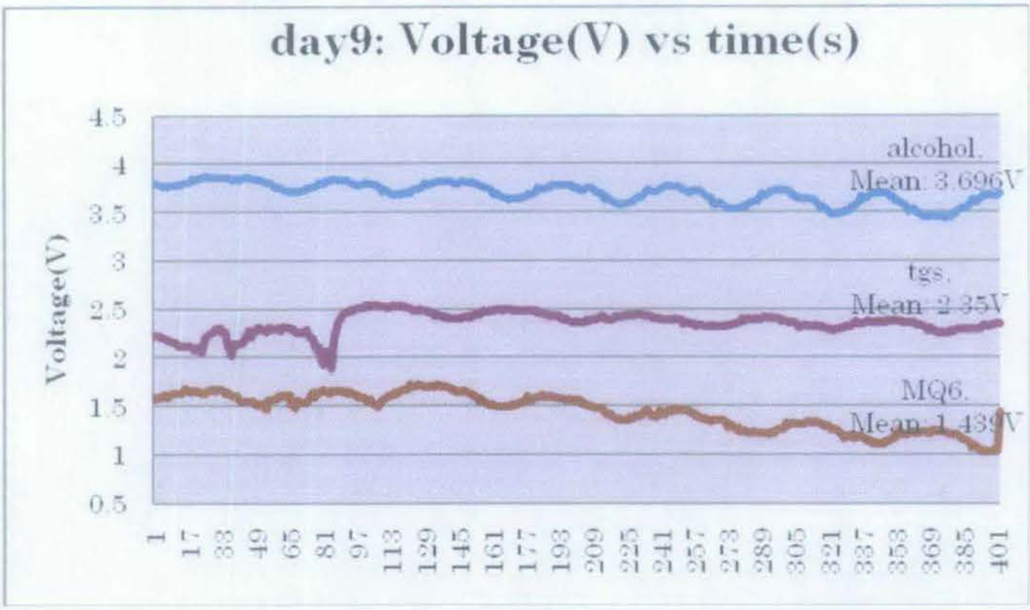


Figure 37: Day9 data values

From figure 37, the reading of day 9 for TGS sensor is 2.35V while for Alcohol sensor is 3.696V and for MQ6 sensor, the reading is 1.439V. In table 15 below, the comparison between the readings of day 1, day 3, day 4, day 8 and day 9 is shown.

Table 9: The data between day 1, day 3, day 4, day 8 and day 9

Type sensor/ reading	Day1 (V)	Day 3 (V)	Day4 (V)	Day 8 (V)	Day9 (V)
TGS sensor	2.3005	2.247	2.364	2.416	2.35
Alcohol Sensor	3.0988	3.264	3.439	3.72	3.696
MQ6 sensor	0.9247	1.023	1.044	1.15	1.439

From table 15, the differences between day 1, day 3, day 4, day 8 and day 9 can be observed. For TGS sensor, the reading decreased around 0.024V from the day8 to day9. For Alcohol sensor, the voltage decreases 0.066V from day 8 to day 9 while for MQ6 sensor, it actually increases for 0.289V from day 8 to day 9.

4.3.6 Day 10 data

Day 10 is taken to see the differences between the rotten and the fresh tomato. The data that has been taken on day 10 is shown in figure 38.

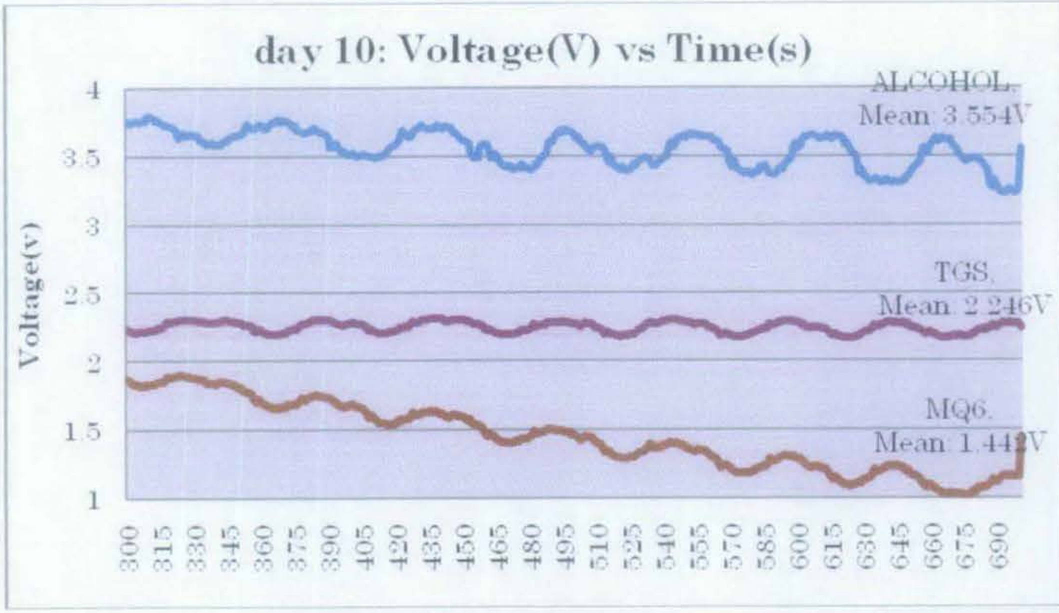


Figure 38: Day 10 data values

From figure 38, the reading of day 10 for TGS sensor is 2.246V while for Alcohol sensor is 3.554V and for MQ6 sensor, the reading is 1.442V. In table 16 below, the comparison between the readings of day1, day3, day8, day9 and day10 is shown.

Table 16: The data between day 1, day 3, day 4, day 8, day 9 and day 10

Type sensor/ reading	Day1 (V)	Day 3 (V)	Day4 (V)	Day 8 (V)	Day9 (V)	Day 10 (V)
TGS sensor	2.3005	2.247	2.364	2.416	2.35	2.246
Alcohol Sensor	3.0988	3.264	3.439	3.72	3.696	3.554
MQ6 sensor	0.9247	1.023	1.044	1.15	1.439	1.442

From table 16, the differences between day 1, day 3, day 8, day 9 and day 10 can be observed. For TGS sensor, the reading decreased around 0.104V from the day10 to day9. For Alcohol sensor, the voltage decreases 0.142V from day 10 to day 9 while for MQ6 sensor, it actually increases for 0.002V from day 10 to day 9.

4.3.7 Day 11 data

Day 11 is set as the last day of the rotten days. Even though it can goes longer than day 11, but in this experiment, it has been determined that day 11 would be the maximum day. The data which has been taken on day 11 is shown in figure 39.

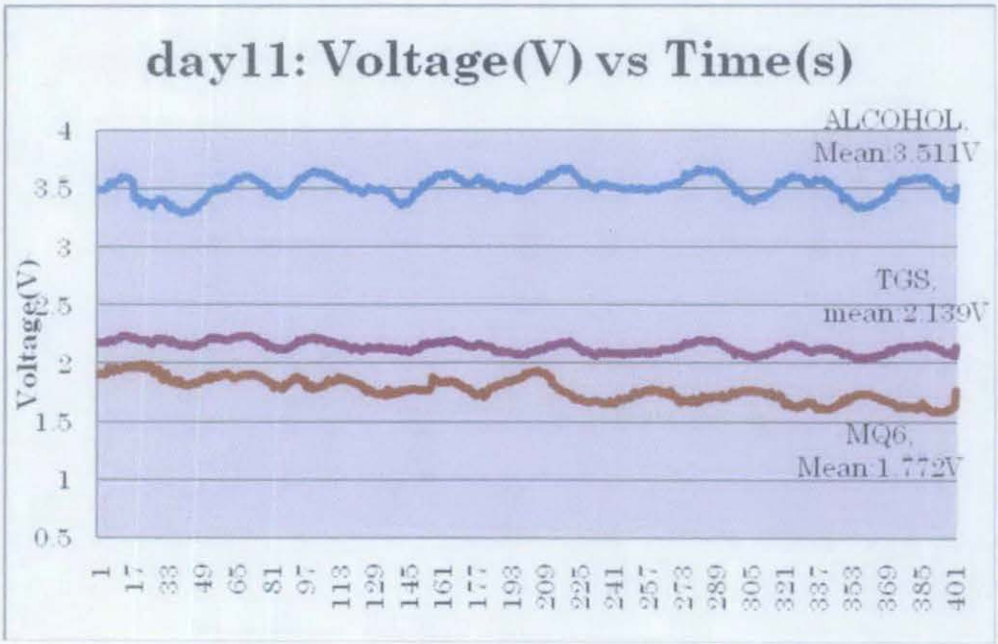


Figure 39: Day 11 data values

From figure 39, the reading of day 9 for TGS sensor is 2.139V while for Alcohol sensor is 3.511V and for MQ6 sensor, the reading is 1.772V. In table 17 below, the comparison between the readings of day1, day3, day8, day9, day 10 and day11 is shown.

Table 17: The data between day 1, day 3, day 4, day 8, day 9, day 10 and day 11

Type sensor/ reading	Day1 (V)	Day 3 (V)	Day4 (V)	Day 8 (V)	Day9 (V)	Day 10 (V)	Day11 (V)

TGS sensor	2.3005	2.247	2.364	2.416	2.35	2.246	2.139
Alcohol Sensor	3.0988	3.264	3.439	3.72	3.696	3.554	3.511
MQ6 sensor	0.9247	1.023	1.044	1.15	1.439	1.442	1.772

From table 17, the differences between day 1, day 3, day 8, day 9, day 10 and day 11 can be observed. For TGS sensor, the reading decreased around 0.043V from the day11 to day10. For Alcohol sensor, the voltage decreases 0.107V from day 11 to day 10 while for MQ6 sensor, it actually increases for 0.33V from day 11 to day 10.

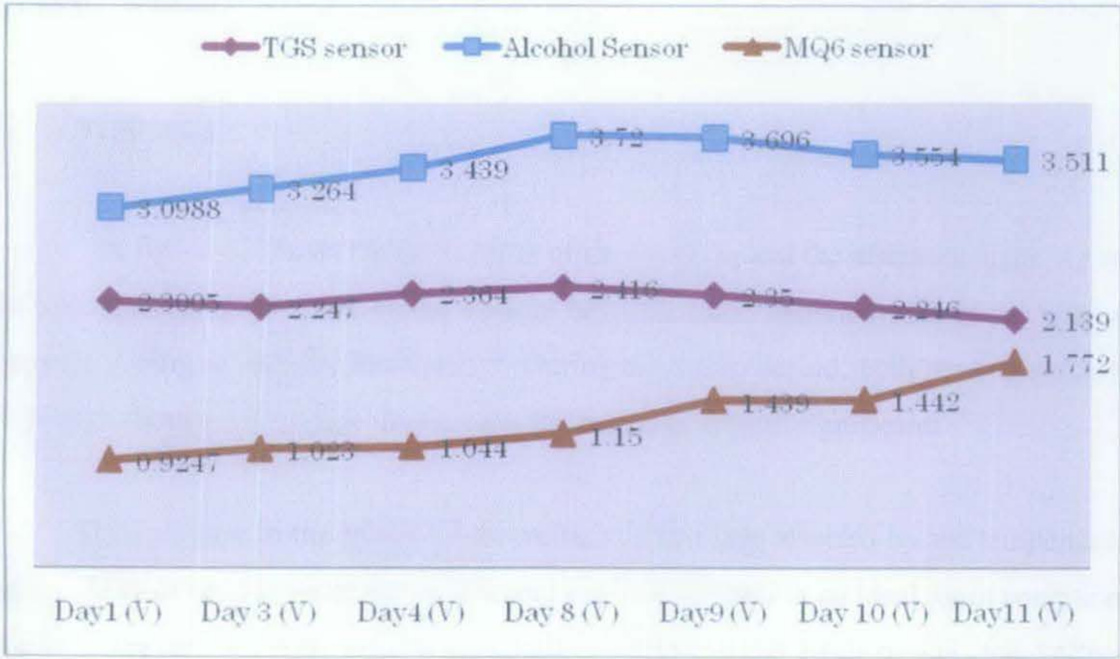


Figure 40: The graph between day 1, day 3, day 4, day 8, day 9, day 10 and day 11

From all the data that has been collected and gathered shown in figure 40, during the fresh state to rotten state, the voltage of the sensor is kept increasing from day 1 to day 8. When the tomato has reach its rotten state as shown from day 9 to day 11, the voltage of TGS sensor and alcohol sensor starts to decreased but the voltage of MQ6 sensor keep increasing.

From the table also, it is shown that the data for still fresh condition for TGS is around 2.3005V to 2.416V and for the rotten state, the value is from 2.35V to 2.139V.

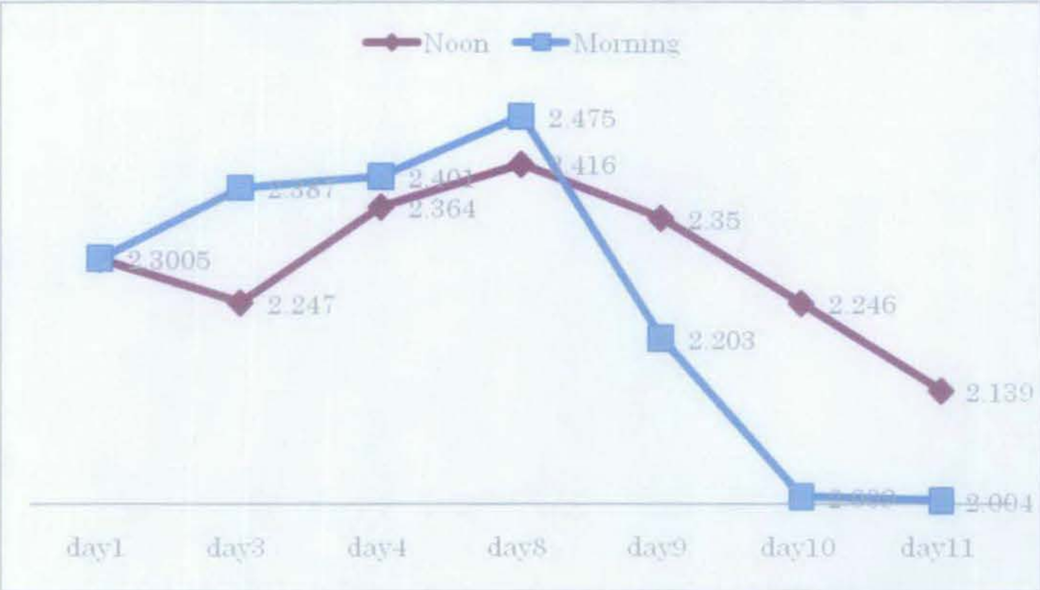


Figure 41: TGS

4.5 ALCOHOL Data

The figure 42 shows the differences of the morning and the afternoon data. As we can see from the graph, both of the sensors have the same pattern which is the voltage keeps increasing during the fresh period. During the rotten period, both reading actually drops even though the voltage drop during the morning is quite significant except for the fact that the readings that was obtained during the morning period is not very stable compare to TGS readings.

The variation in the values of the voltage is possibly affected by the temperature and humidity of the day since the experiment is not conducted in an ideal room condition. Based on the observation, we can conclude that during the fresh period, the voltage increases and during the rotten condition, the voltage drops.

Figure 42: ALCOHOL

4.6 MQ6 Data

The figure 43 shows the differences of the morning and the afternoon data. As we can see from the graph, both of the sensors have the same pattern which is the voltage keeps increasing during the fresh period and rotten period. Therefore, for MQ6 sensor, it is safe to say that either during fresh condition and rotten condition, the voltages will still increases.

Figure 43: MQ6

4.7 All Data

Figure 44 shows the comparisons between all three sensors for both morning and afternoon. From the graph we can actually sees that during the first 8 day; which is during the fresh condition, all three sensor voltage readings are increasing but during the rotten period, both TGS sensor and ALCOHOL sensor's voltage is decreasing. For the MQ6 sensor, even during the rotten day; which is during the 9th day and upwards, the voltage is still increasing.

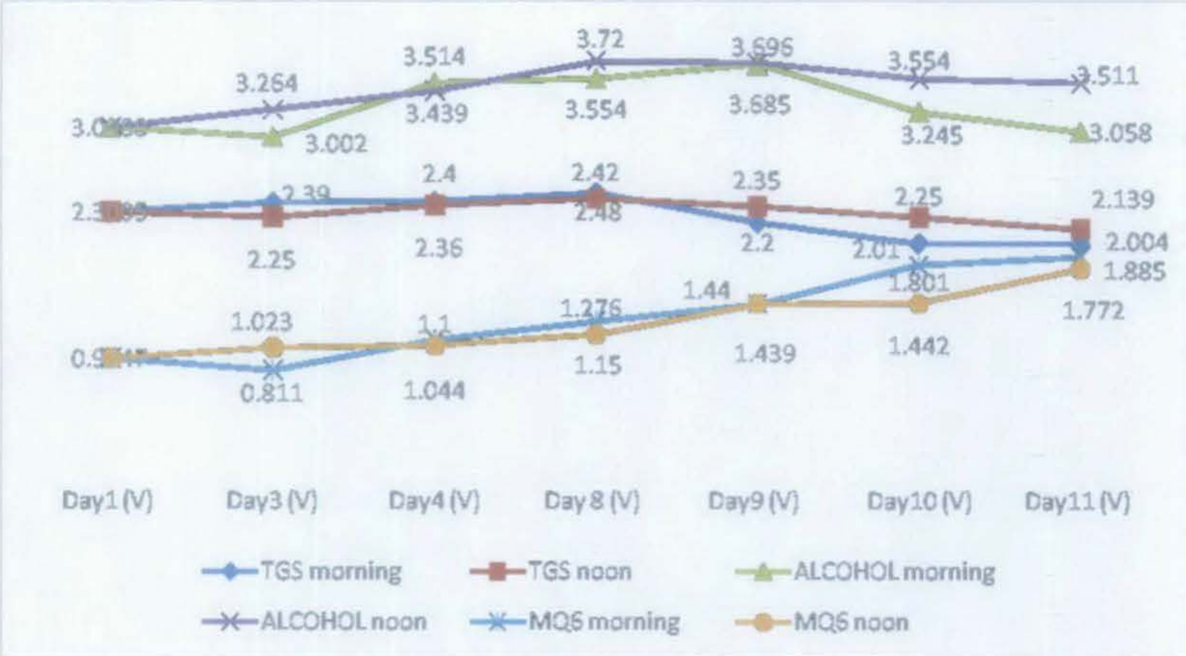
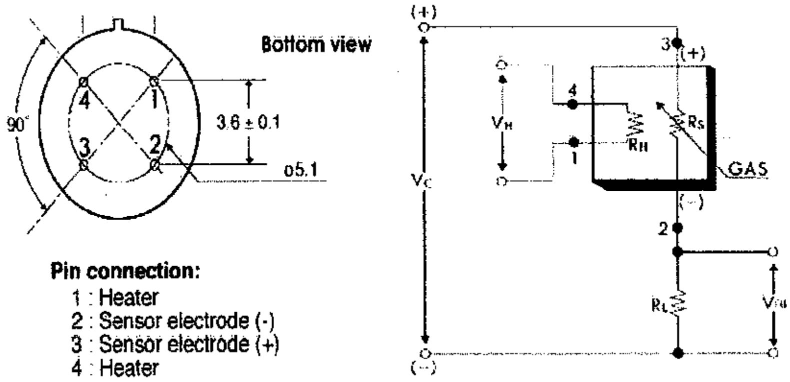


Figure 44: All Data

APPENDIX A

SENSOR'S INTERNAL CIRCUIT

i. TGS Sensor internal Circuits:



ii. Alcohol Sensor internal circuits:

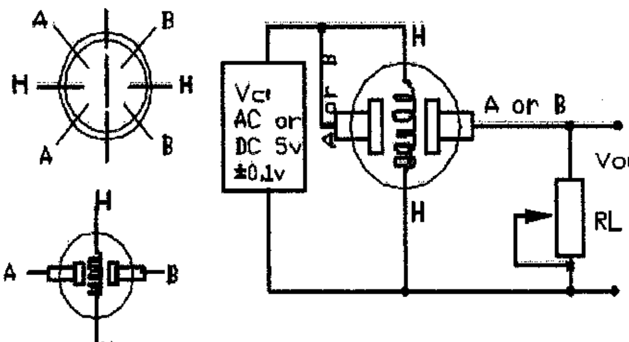


Fig 2

iii. MQ6 Sensor internal circuits:

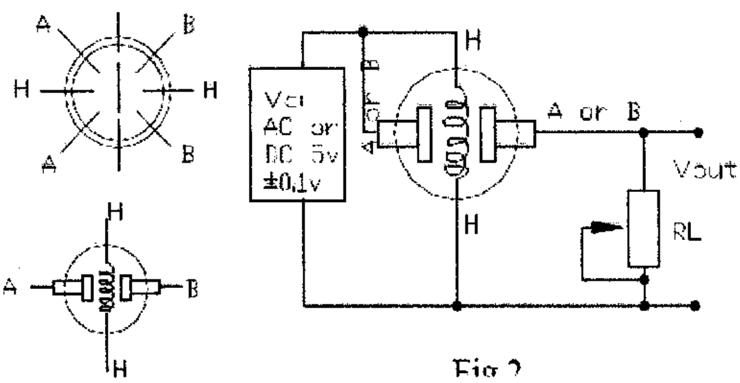


Fig 2

e) Sensitivity characteristic curve

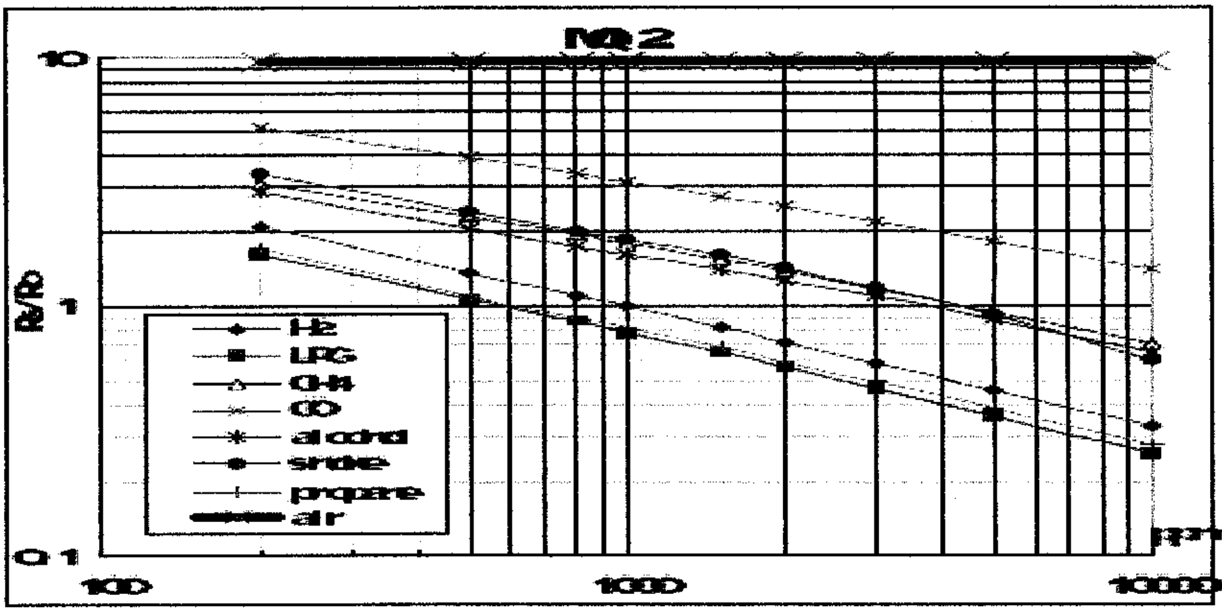


Figure3: Sensitivity characteristic curve of several gasses

In figure, it shows the typical sensitivity characteristics of the MQ-2 for several gases. In their:

- Temp: 20°C
- Humidity: 65%
- O_2 concentration: 21%
- R_L=5K
- R_0: sensor resistance at 1000ppm of H_2 in the clean air
- R_S: sensor resistance at various concentrations of gases

MQ-6 sensor specification

a) Standard work condition

Symbol	Parameter Name	Technical condition	Remarks
V_C	Circuit voltage	5V±0.1	AC or DC
V_H	Heating voltage	5V±0.1	AC or DC
R_L	Load resistance	20K Ω	
R_H	Heater resistance	33Ω±5%	Room temp
P_H	Heating consumption	Less than 750mw	

b) Environment condition

Symbol	Parameter Name	Technical Condition	Remarks
T_{ao}	Using temp	-10°C-50°C	
T_{as}	Storage temp	-20°C-50°C	
R_H	Related humidity	Less than 95% Rh	
O_2	Oxygen concentration	21%(standard condition)Oxygen concentration can affect sensitivity	Minimum value is over 2%

c) Sensitivity characteristic

Symbol	Parameter Name	Technical Condition	Remarks
Rs	Sensing resistance	10KΩ-60KΩ (1000ppm iso-butane)	Detecting concentration scope: 200ppm-1000ppm LPG, iso-butane, propane, LNG
a (3000/1000) isobutene	Concentration Slope Rate	≤0.6	
Standard Detecting Condition	Temp: 20°C±2°C Vc:5V±0.1 Humidity: 65%±5% Vh:5V±0.1		
Preheat Time	Over 24 hour		

d) Sensitivity characteristics of the MQ-6

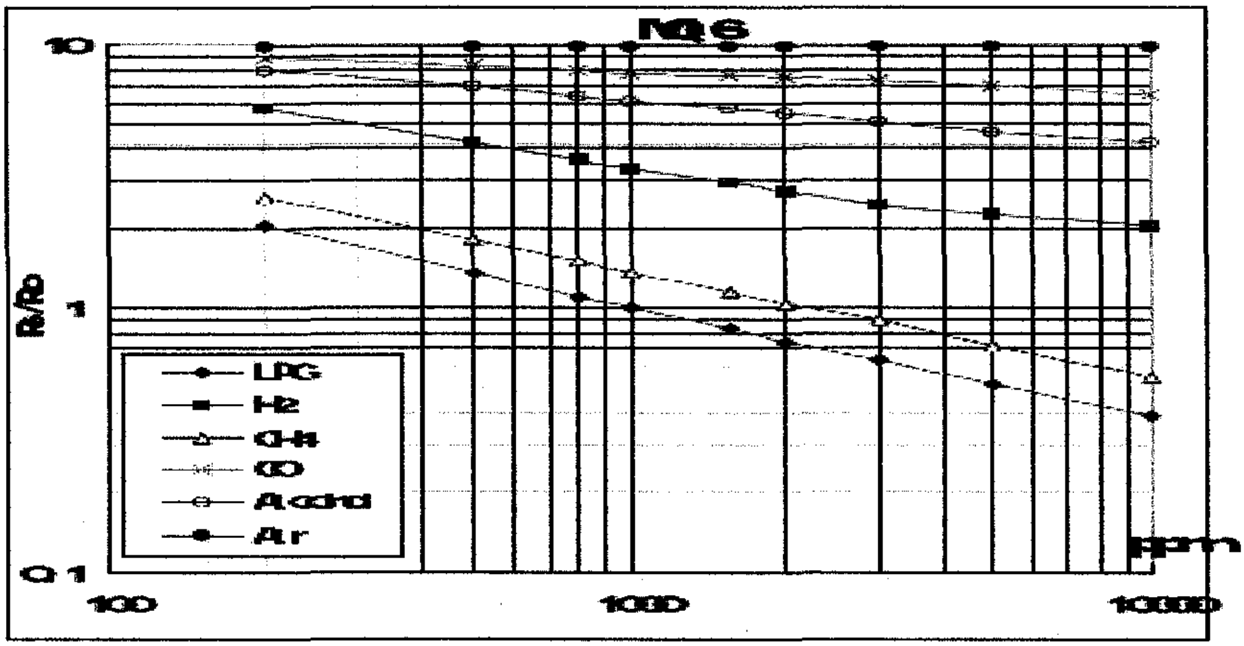


Figure4: Sensitivity characteristics of MQ-6

In the figure, it shows the typical sensitivity characteristics of the MQ-6 for several gases. In their:

- Temp: 20ºC
- Humidity: 65%
- O_2 concentration: 21%
- R_L=5K
- R_0: sensor resistance at 1000ppm of H_2 in the clean air
- R_S: sensor resistance at various concentrations of gases

MQ-8 sensor specification

a) Standard work condition

Symbol	Parameter Name	Technical condition	Remarks
V_C	Circuit voltage	5V±0.1	AC or DC
V_H	Heating voltage	5V±0.1	AC or DC
R_L	Load resistance	10K Ω	
R_H	Heater resistance	31Ω±5%	Room temp
P_H	Heating consumption	Less than 800mw	

b) Environment condition

Symbol	Parameter Name	Technical Condition	Remarks
T_{ao}	Using temp	-10°C-50°C	
T_{as}	Storage temp	-20°C-70°C	
R_H	Related humidity	Less than 95% Rh	
O_2	Oxygen concentration	21%(standard condition)Oxygen concentration can affect sensitivity	Minimum value is over 2%

c) Sensitivity characteristic

Symbol	Parameter Name	Technical Condition	Remarks
R_S	Sensing resistance	10KΩ-60KΩ (1000ppm H_2)	Detecting concentration scope: 100ppm-1000ppm Hydrogen(H_2)
a (3000/1000) isobutene	Concentration Slope Rate	≤0.6	
Standard Detecting Condition	Temp: 20°C±2°C Vc:5V±0.1 Humidity: 65%±5% Vh:5V±0.1		
Preheat Time	Over 24 hour		

d) Sensitivity characteristics of the MQ-8

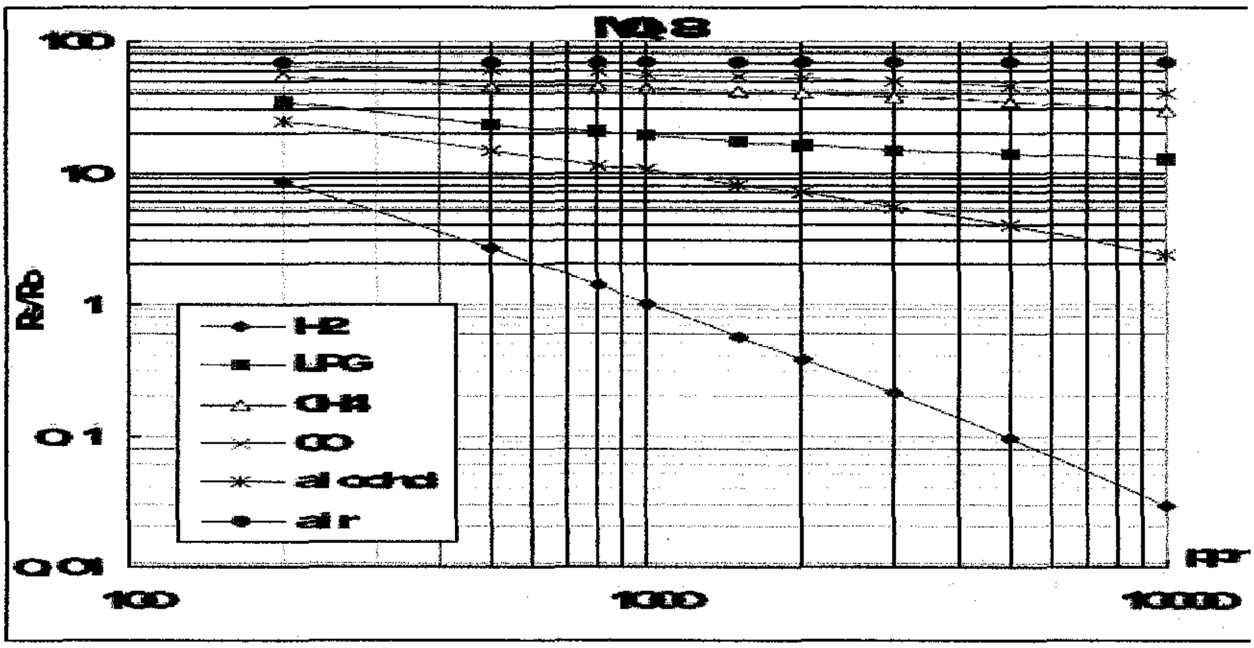


Figure5: Sensitivity characteristics of MQ-8

In the figure, it shows the typical sensitivity characteristics of the MQ-8 for several gases.
In their:

- Temp: 20°C
- Humidity: 65%
- O_2 concentration: 21%
- R_L=10K
- R_0: sensor resistance at 1000ppm of H_2 in the clean air
- R_S: sensor resistance at various concentrations of gases

APPLICATION

They are suitable for alcohol checker, Breathalyser.

SPECIFICATIONS

A. Standard work condition

Symbol	Parameter name	Technical condition	Remarks
Vc	Circuit voltage	5V±0.1	AC OR DC
V_H	Heating voltage	5V±0.1	AC OR DC
R_L	Load resistance	200KΩ	
R_H	Heater resistance	33Ω±5%	Room Tem
P_H	Heating consumption	less than 750mw	

B. Environment condition

Symbol	Parameter name	Technical condition	Remarks
Tao	Using Tem	-10℃-50℃	
Tas	Storage Tem	-20℃-70℃	
R_H	Related humidity	less than 95%Rh	
O_2	Oxygen concentration	21%(standard condition) Oxygen concentration can affect sensitivity	minimum value is over 2%

C. Sensitivity characteristic

Symbol	Parameter name	Technical parameter	Remarks
Rs	Sensing Resistance	1MΩ- 8 MΩ (0.4mg/L alcohol)	Detecting concentration scope: 0.05mg/L—10mg/L Alcohol
α (0.4/1 mg/L)	Concentration slope rate	≤0.6	
Standard detecting condition	Temp: 20℃±2℃ Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1		
Preheat time	Over 24 hour		

D. Structure and configuration, basic measuring circuit

	Parts	Materials
1	Gas sensing layer	SnO_2
2	Electrode	Au
3	Electrode line	Pt
4	Heater coil	Ni-Cr alloy
5	Tubular ceramic	Al_2O_3
6	Anti-explosion network	Stainless steel gauze (SUS316 100-mesh)
7	Clamp ring	Copper plating Ni
8	Resin base	Bakelite
9	Tube Pin	Copper plating Ni

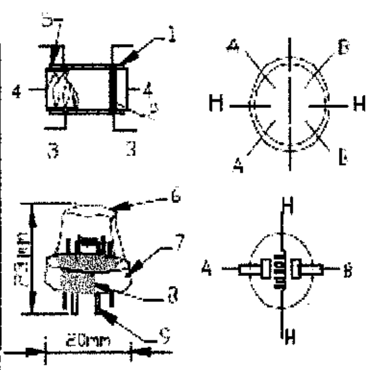


Fig. 1

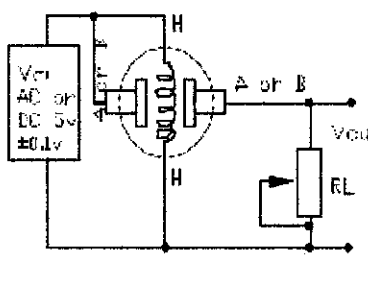
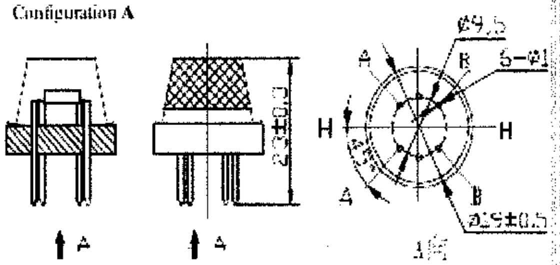
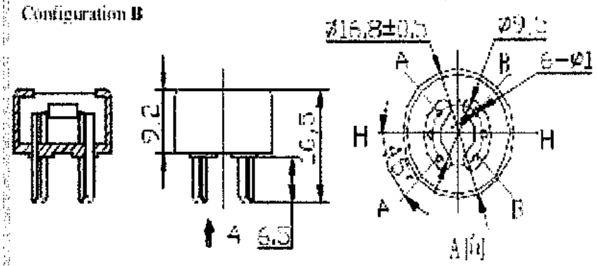


Fig.2

Configuration A



Configuration B



E. Sensitivity characteristic curve

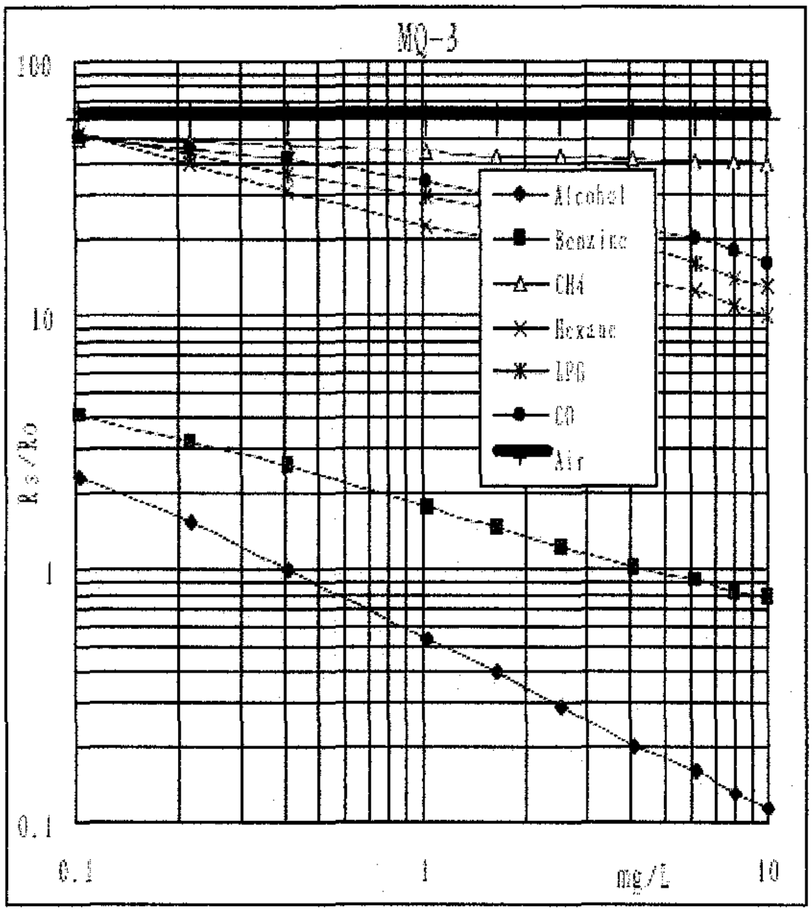


Fig.2 sensitivity characteristics of the MQ-3

Fig.3 is shows the typical sensitivity characteristics of the MQ-3 for several gases.
in their: Temp: 20℃、
Humidity: 65%、
O_2concentration 21%
RL=200kΩ
Ro: sensor resistance at 0.4mg/L of
Alcohol in the clean air.
Rs: sensor resistance at various concentrations of gases.

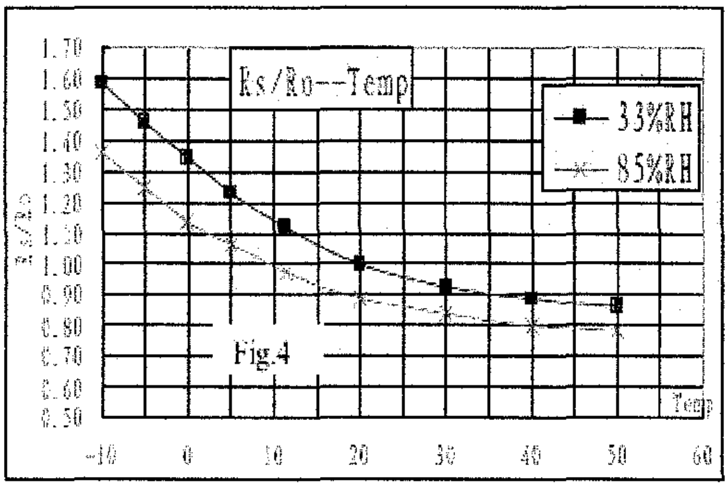


Fig.4 is shows the typical dependence of the MQ-3 on temperature and humidity.
Ro: sensor resistance at 0.4mg/L of Alcohol in air at 33%RH and 20 ℃
Rs: sensor resistance at 0.4mg/L of Alcohol at different temperatures and humidities.

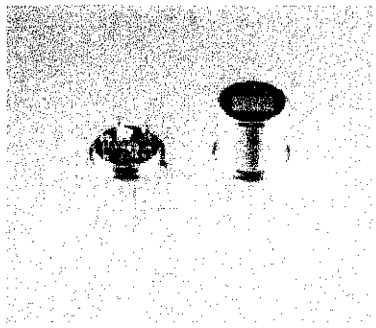
TGS 2600 - for the detection of Air Contaminants

Features:

* Low power consumption
* High sensitivity to gaseous air contaminants
* Long life and low cost
* Uses simple electrical circuit
* Small size

Applications:

* Air cleaners
* Ventilation control
* Air quality monitors



The sensing element is comprised of a metal oxide semiconductor layer formed on an alumina substrate of a sensing chip together with an integrated heater. In the presence of a detectable gas, the sensor's conductivity increases depending on the gas concentration in the air. A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration.

The **TGS 2600** has high sensitivity to low concentrations of gaseous air contaminants such as hydrogen and carbon monoxide which exist in cigarette smoke. The sensor can detect hydrogen at a level of several ppm. Figaro also offers a microprocessor (FIC93619A) which contains special software for handling the sensor's signal for appliance control applications.

Due to miniaturization of the sensing chip, TGS 2600 requires a heater current of only 42mA and the device is housed in a standard TO-5 package.

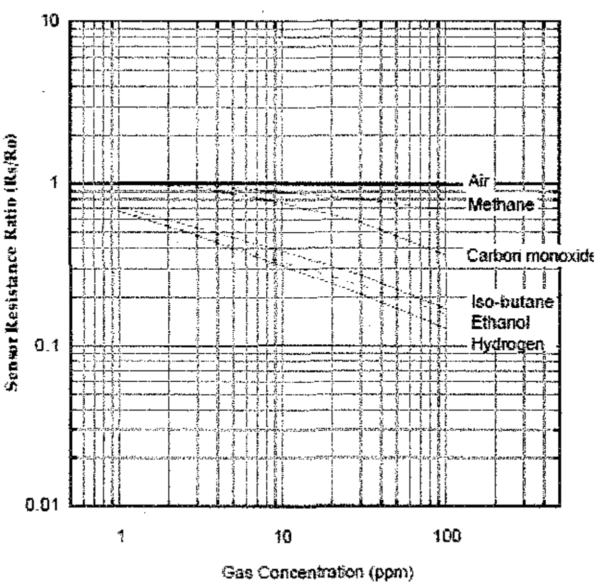
The figure below represents typical sensitivity characteristics, all data having been gathered at standard test conditions (see reverse side of this sheet). The Y-axis is indicated as *sensor resistance ratio* (Rs/Ro) which is defined as follows:

Rs = Sensor resistance in displayed gases at various concentrations
Ro = Sensor resistance in fresh air

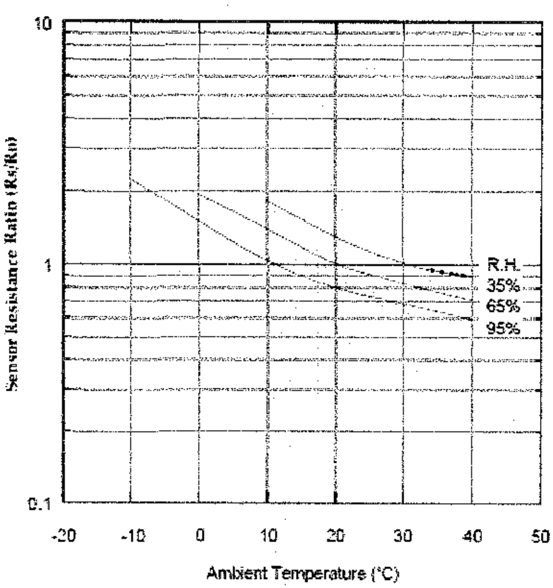
The figure below represents typical temperature and humidity dependency characteristics. Again, the Y-axis is indicated as *sensor resistance ratio* (Rs/Ro), defined as follows:

Rs = Sensor resistance in fresh air at various temperatures/humidities
Ro = Sensor resistance in fresh air at 20°C and 65% R.H.

Sensitivity Characteristics:

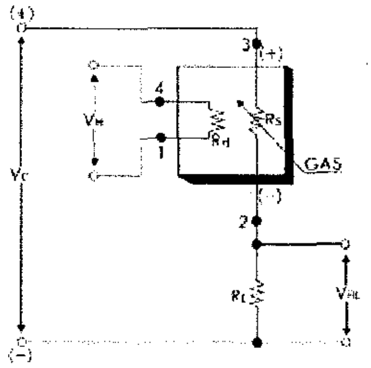


Temperature/Humidity Dependency:



Basic Measuring Circuit:

The sensor requires two voltage inputs: heater voltage (V_H) and circuit voltage (V_C). The heater voltage (V_H) is applied to the integrated heater in order to maintain the sensing element at a specific temperature which is optimal for sensing. Circuit voltage (V_C) is applied to allow measurement of voltage (Vout) across a load resistor (R_L) which is connected in series with the sensor. DC voltage is required for the circuit voltage since the sensor has a polarity. A common power supply circuit can be used for both V_C and V_H to fulfill the sensor's electrical requirements. The value of the load resistor (R_L) should be chosen to optimize the alarm threshold value, keeping power consumption (P_S) of the semiconductor below a limit of 15mW. Power consumption (P_S) will be highest when the value of Rs is equal to R_L on exposure to gas.



Specifications:

Model number			TGS 2600	
Sensing element type			D1	
Standard package			TO-5 metal can	
Target gases			Air contaminants	
Typical detection range			1 ~ 10 ppm of H_2	
Standard circuit conditions	Heater voltage	V_H	5.0±0.2V DC/AC	
	Circuit voltage	V_C	5.0±0.2V DC	$P_S \leq 15$mW
	Load resistance	R_L	Variable	$P_S \leq 15$mW
Electrical characteristics under standard test conditions	Heater resistance	R_H	approx. 83Ω at room temp. (typical)	
	Heater current	I_H	42±4mA	
	Heater power consumption	P_H	210mW	V_H=5.0V DC
	Sensor resistance	Rs	10k~90kΩ in air	
	Sensitivity (change ratio of Rs)		0.3~0.6	$\frac{\text{Rs (10ppm of } H_2)}{\text{Rs (air)}}$
Standard test conditions	Test gas conditions		normal air at 20±2°C, 65±5%RH	
	Circuit conditions		V_C = 5.0±0.01V DC V_H = 5.0±0.05V DC	
	Conditioning period before test		7 days	

The value of power consumption (P_S) can be calculated by utilizing the following formula:

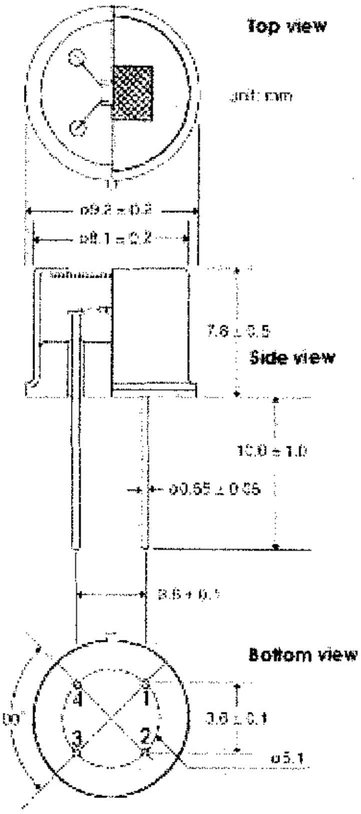
$$P_S = \frac{(V_C - V_{out})^2}{R_S}$$

Sensor resistance (Rs) is calculated with a measured value of Vout by using the following formula:

$$R_S = \frac{V_C \times R_L}{V_{out}} - R_L$$

For information on warranty, please refer to Standard Terms and Conditions of Sale of Figaro USA Inc.

Structure and Dimensions:



Pin connection:
1 : Heater
2 : Sensor electrode (-)
3 : Sensor electrode (+)
4 : Heater

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APPENDIX C

TEST RESULT AND DATA

i. Initial Readings (first 80 data)

Time	TGS	ALCOHOL	MQ6
0	0.1111	0.694	0.1752
1	0.1215	0.708	0.4077
2	0.1593	0.8301	0.766
3	0.2246	1.0736	1.1481
4	0.318	1.4118	1.4545
5	0.4212	1.7298	1.6834
6	0.5249	1.9678	1.8445
7	0.6159	2.0966	1.9471
8	0.7093	2.2498	2.0197
9	0.8026	2.4647	2.0808
10	0.8795	2.6142	2.1198
11	0.9302	2.6673	2.14
12	0.9674	2.6899	2.1491
13	1.0028	2.7558	2.1607
14	1.0248	2.7711	2.1625
15	1.0492	2.8346	2.1699
16	1.0456	2.7796	2.1595
17	1.0443	2.7583	2.157
18	1.0462	2.7595	2.154
19	1.0431	2.754	2.1516
20	1.0401	2.7534	2.1485
21	1.0346	2.7467	2.1461
22	0.9992	2.6185	2.1235
23	0.9717	2.5245	2.1082
24	0.9613	2.5001	2.1015
25	0.9577	2.5135	2.1064
26	0.9528	2.5214	2.107
27	0.9461	2.5092	2.1039
28	0.932	2.4732	2.0997
29	0.9143	2.4213	2.0905
30	0.8997	2.3884	2.0844
31	0.8881	2.3621	2.0838
32	0.8808	2.3481	2.0832
33	0.8832	2.367	2.0911
34	0.8856	2.3884	2.0972
35	0.8795	2.3756	2.0972
36	0.8734	2.3634	2.0954
37	0.8814	2.4061	2.1046
38	0.8924	2.4647	2.1137
39	0.8795	2.4226	2.1088
40	0.8618	2.3609	2.1003
41	0.8557	2.3487	2.1003
42	0.8563	2.3597	2.1015
43	0.8386	2.298	2.0917
44	0.8472	2.3432	2.0997
45	0.8557	2.3811	2.107
46	0.8655	2.4244	2.1155
47	0.8625	2.4232	2.1168
48	0.893	2.5434	2.1381
49	0.9009	2.5867	2.143
50	0.9101	2.6283	2.1516
51	0.9156	2.6551	2.1564
52	0.9198	2.6746	2.1613
53	0.9314	2.7284	2.1735
54	0.9626	2.8565	2.1906
55	0.9839	2.9426	2.2022
56	0.9857	2.9536	2.2034
57	0.9796	2.9426	2.1998
58	0.9882	2.9841	2.2059
59	1.0059	3.0586	2.2163
60	1.0175	3.1068	2.2236
61	1.0224	3.1257	2.2279
62	1.0114	3.0915	2.2272
63	1.0218	3.1379	2.2217
64	1.0205	3.1361	2.2175
65	1.0041	3.0818	2.2059
66	0.9967	3.0512	2.201
67	0.9937	3.0433	2.1998
68	0.9821	2.9933	2.1912
69	0.9803	2.9933	2.1924
70	0.9638	2.9328	2.1802
71	0.9418	2.8388	2.1662
72	0.9333	2.8083	2.1625
73	0.9241	2.7741	2.1589
74	0.9137	2.7326	2.1546
75	0.9082	2.7137	2.1516
76	0.9015	2.6832	2.1467
77	0.8643	2.5312	2.1241
78	0.8405	2.4421	2.1119
79	0.8307	2.3951	2.1064
80	0.8264	2.378	2.1046

ii. Day 1 (first 80 data)

time(s)	TGS	ALCOHOL	mq6
300	2.2907	2.9023	0.9119
301	2.2755	2.8211	0.8844
302	2.2706	2.776	0.8716
303	2.2645	2.7467	0.8631
304	2.2639	2.7393	0.8606
305	2.2669	2.7515	0.8637
306	2.2639	2.7436	0.8625
307	2.2578	2.7186	0.8582
308	2.2523	2.6814	0.8441
309	2.2462	2.6374	0.8295
310	2.2425	2.616	0.8234
311	2.2407	2.6026	0.8197
312	2.2394	2.5922	0.8148
313	2.2407	2.6069	0.8185
314	2.2443	2.6234	0.8234
315	2.2364	2.5837	0.8106
316	2.2333	2.5642	0.8039
317	2.2358	2.5806	0.8087
318	2.2394	2.6081	0.8179
319	2.2419	2.6258	0.8222
320	2.2407	2.6295	0.8234
321	2.2431	2.6392	0.8246
322	2.2376	2.6099	0.8155
323	2.2309	2.5703	0.8057
324	2.2364	2.602	0.8148
325	2.2346	2.5941	0.8112
326	2.2376	2.6032	0.8148
327	2.2327	2.5904	0.81
328	2.2266	2.555	0.7996
329	2.2346	2.5983	0.8112
330	2.2388	2.6222	0.8185
331	2.2431	2.6435	0.8252
332	2.2443	2.6624	0.8307
333	2.2462	2.6679	0.8325
334	2.2645	2.7638	0.8588
335	2.2681	2.7918	0.8686
336	2.2736	2.8278	0.8771
337	2.2761	2.8425	0.8838
338	2.2816	2.8694	0.893
339	2.3078	3.0323	0.9387
340	2.3176	3.083	0.9516
341	2.3157	3.0738	0.9503
342	2.3151	3.0757	0.9497
343	2.3206	3.1037	0.9565
344	2.3286	3.1477	0.9687
345	2.3347	3.1904	0.9809
346	2.3389	3.2118	0.9888
347	2.342	3.227	0.9925
348	2.3371	3.2014	0.9851
349	2.342	3.2301	0.9937
350	2.345	3.2551	1.0004
351	2.3389	3.2209	0.9876
352	2.3334	3.1861	0.9796
353	2.3322	3.1782	0.9766
354	2.3261	3.1422	0.9656
355	2.3249	3.1336	0.9632
356	2.3103	3.0464	0.9357
357	2.3066	3.0207	0.9272
358	2.3035	2.9963	0.9198
359	2.2974	2.9719	0.9137
360	2.2938	2.953	0.9076
361	2.2883	2.9292	0.9009
362	2.2651	2.7888	0.8588
363	2.251	2.7058	0.8356
364	2.2517	2.7064	0.8325
365	2.2523	2.7149	0.8362
366	2.251	2.7155	0.8356
367	2.2498	2.7076	0.8338
368	2.2474	2.6948	0.8301
369	2.2413	2.6545	0.8179
370	2.2333	2.6075	0.8045
371	2.2279	2.58	0.7959
372	2.2266	2.5544	0.7892
373	2.2309	2.5849	0.7971
374	2.2266	2.5416	0.7837
375	2.2285	2.5373	0.7819
376	2.2285	2.5367	0.7813
377	2.2327	2.5697	0.791
378	2.234	2.5886	0.7959
379	2.2388	2.6228	0.8069
380	2.234	2.599	0.8008

iii. Day 3 (first 80 data)

time(s)	TGS	ALCOHOL	MQ6
300	2.3621	3.3894	1.2854
301	2.3603	3.3845	1.2806
302	2.3579	3.3845	1.2769
303	2.353	3.3863	1.2775
304	2.3542	3.3638	1.2549
305	2.353	3.3595	1.2531
306	2.3579	3.3668	1.2549
307	2.3432	3.3369	1.2354
308	2.3267	3.3259	1.2268
309	2.331	3.3216	1.2232
310	2.3267	3.3155	1.2214
311	2.3164	3.329	1.2311
312	2.2962	3.3546	1.2513
313	2.2791	3.3406	1.2378
314	2.2907	3.3442	1.2366
315	2.2858	3.357	1.2421
316	2.2803	3.3229	1.2128
317	2.2748	3.3125	1.2055
318	2.2669	3.3027	1.2
319	2.2578	3.2972	1.1933
320	2.2681	3.2844	1.1823
321	2.2712	3.2167	1.1335
322	2.2718	3.2209	1.1341
323	2.2694	3.2319	1.142
324	2.2645	3.1867	1.109
325	2.2834	3.1898	1.1097
326	2.2724	3.1611	1.0871
327	2.2803	3.1648	1.0907
328	2.2938	3.1648	1.0883
329	2.295	3.152	1.0791
330	2.2944	3.1642	1.0828
331	2.3133	3.1642	1.0822
332	2.3243	3.1703	1.0858
333	2.3133	3.2026	1.106
334	2.3176	3.1886	1.0981
335	2.3328	3.2105	1.1121
336	2.3341	3.2319	1.1261
337	2.3426	3.2374	1.1298
338	2.3481	3.2441	1.1371
339	2.3493	3.2514	1.1396
340	2.3341	3.2661	1.1475
341	2.342	3.3406	1.203
342	2.3481	3.321	1.1908
343	2.3499	3.3003	1.1762
344	2.3487	3.3375	1.2012
345	2.3499	3.3558	1.214
346	2.3359	3.3491	1.203
347	2.3249	3.3576	1.2104
348	2.331	3.3772	1.2189
349	2.3145	3.379	1.2226
350	2.3035	3.3644	1.2104
351	2.3054	3.3668	1.2116
352	2.3096	3.3845	1.2244
353	2.3096	3.3784	1.2195
354	2.3005	3.3735	1.2177
355	2.2767	3.3699	1.2134
356	2.2791	3.3699	1.211
357	2.2962	3.3351	1.178
358	2.2999	3.3497	1.189
359	2.2956	3.3332	1.1731
360	2.2828	3.3088	1.1536
361	2.2633	3.3015	1.1487
362	2.2651	3.2917	1.142
363	2.2639	3.2881	1.1371
364	2.2486	3.2923	1.139
365	2.2449	3.307	1.1426
366	2.2468	3.3131	1.1457
367	2.2419	3.3161	1.1463
368	2.2443	3.3149	1.1438
369	2.2364	3.3082	1.139
370	2.2364	3.2997	1.1328
371	2.2376	3.2887	1.1249
372	2.2327	3.2386	1.0877
373	2.248	3.1825	1.0523
374	2.248	3.2362	1.084
375	2.2394	3.2124	1.0657
376	2.2565	3.1812	1.0425
377	2.2559	3.1849	1.0443
378	2.2547	3.1678	1.0303
379	2.2523	3.144	1.0077
380	2.2529	3.1629	1.0224

iv. Day 4 (first 80 data)

time(s)	TGS	ALCOHOL	MQ6
300	2.5056	3.5078	1.3007
301	2.5043	3.5096	1.2915
302	2.4946	3.4913	1.286
303	2.5092	3.517	1.2787
304	2.5166	3.5304	1.2519
305	2.5105	3.52	1.2152
306	2.4958	3.4962	1.2299
307	2.508	3.5188	1.2317
308	2.4812	3.4712	1.2104
309	2.4903	3.4883	1.1982
310	2.5062	3.5182	1.1872
311	2.508	3.5255	1.1768
312	2.4995	3.5072	1.1762
313	2.4909	3.4938	1.1744
314	2.4982	3.5066	1.1676
315	2.5086	3.5304	1.1725
316	2.5056	3.5261	1.1744
317	2.5141	3.5395	1.1756
318	2.5233	3.5572	1.1902
319	2.5153	3.5475	1.1829
320	2.5105	3.542	1.2012
321	2.5196	3.5603	1.2116
322	2.5141	3.5487	1.2104
323	2.5135	3.5487	1.2104
324	2.5141	3.5499	1.2091
325	2.5062	3.5377	1.211
326	2.5043	3.5365	1.2104
327	2.4873	3.5102	1.2073
328	2.483	3.5035	1.2146
329	2.4793	3.4986	1.2226
330	2.4769	3.4944	1.2519
331	2.472	3.4864	1.261
332	2.4641	3.4742	1.2183
333	2.4409	3.4339	1.1988
334	2.4354	3.423	1.1872
335	2.436	3.4248	1.1817
336	2.4433	3.4388	1.1823
337	2.4702	3.4901	1.1884
338	2.4726	3.4962	1.1957
339	2.4769	3.5029	1.2146
340	2.4744	3.4999	1.2574
341	2.4708	3.4968	1.2311
342	2.4683	3.4907	1.2372
343	2.461	3.4822	1.2598
344	2.4403	3.448	1.2653
345	2.4305	3.4303	1.2769
346	2.4421	3.451	1.2806
347	2.4219	3.4156	1.2696
348	2.4219	3.4187	1.2769
349	2.4024	3.3845	1.2775
350	2.4116	3.4022	1.2702
351	2.4085	3.3992	1.2683
352	2.4006	3.3869	1.2653
353	2.4061	3.3973	1.2476
354	2.4049	3.3973	1.25
355	2.4079	3.4016	1.2305
356	2.414	3.4187	1.2183
357	2.4152	3.4193	1.2116
358	2.4262	3.4413	1.2055
359	2.4287	3.4462	1.1969
360	2.4299	3.4504	1.175
361	2.4335	3.4571	1.1383
362	2.4311	3.4535	1.1371
363	2.4244	3.4486	1.153
364	2.4195	3.4388	1.153
365	2.4183	3.4376	1.1402
366	2.4158	3.4376	1.1274
367	2.4171	3.4394	1.1145
368	2.4201	3.4449	1.1121
369	2.4219	3.4504	1.1121
370	2.4262	3.4571	1.1078
371	2.4409	3.4822	1.1035
372	2.4561	3.5163	1.0938
373	2.4427	3.4895	1.084
374	2.4616	3.5243	1.0773
375	2.4561	3.5182	1.0767
376	2.4732	3.5475	1.0858
377	2.4677	3.5389	1.0981
378	2.4757	3.5536	1.1182
379	2.4683	3.5444	1.1261
380	2.4665	3.5444	1.1182

v. Day 8 (first 80 data)

time(s)	TGS	ALCOHOL	MQ6
300	2.4494	3.7825	1.4801
301	2.461	3.7989	1.4942
302	2.4549	3.7904	1.4832
303	2.4555	3.7892	1.4838
304	2.4659	3.8075	1.4997
305	2.4696	3.8154	1.5009
306	2.472	3.8173	1.5021
307	2.4732	3.8203	1.504
308	2.4738	3.8227	1.5033
309	2.4775	3.8258	1.5052
310	2.4805	3.8319	1.5101
311	2.5001	3.8618	1.5387
312	2.5111	3.8826	1.5528
313	2.4964	3.8581	1.5259
314	2.494	3.8575	1.5241
315	2.5086	3.8789	1.543
316	2.5123	3.8868	1.5479
317	2.5111	3.8862	1.5461
318	2.5239	3.907	1.5644
319	2.5202	3.9051	1.5571
320	2.519	3.9015	1.5528
321	2.5202	3.9033	1.5516
322	2.5239	3.9094	1.5558
323	2.5184	3.9009	1.5467
324	2.5166	3.8972	1.5442
325	2.519	3.9003	1.5436
326	2.5135	3.8942	1.5345
327	2.5013	3.8734	1.5137
328	2.5068	3.8838	1.5204
329	2.5141	3.8954	1.5302
330	2.5129	3.8923	1.5271
331	2.5111	3.8942	1.5253
332	2.5092	3.8905	1.5223
333	2.5105	3.8929	1.5204
334	2.4976	3.8722	1.4997
335	2.4964	3.8704	1.4948
336	2.4818	3.8472	1.4716
337	2.4781	3.8404	1.4606
338	2.4757	3.835	1.4557
339	2.4677	3.8221	1.4429
340	2.4384	3.769	1.3929
341	2.4458	3.7825	1.4069
342	2.4439	3.7788	1.4008
343	2.4323	3.7599	1.3837
344	2.4281	3.7513	1.3721
345	2.4262	3.7501	1.3684
346	2.4122	3.7281	1.3459
347	2.411	3.73	1.3453
348	2.4097	3.7312	1.3428
349	2.4091	3.7294	1.3379
350	2.4055	3.722	1.3294
351	2.4067	3.7294	1.3337
352	2.4061	3.7318	1.3312
353	2.4049	3.7288	1.3263
354	2.4036	3.7312	1.3276
355	2.4158	3.7519	1.3453
356	2.4079	3.7416	1.333
357	2.4146	3.7519	1.3398
358	2.4256	3.7721	1.3569
359	2.4274	3.7776	1.3587
360	2.4299	3.7825	1.3617
361	2.4329	3.7904	1.366
362	2.4482	3.8166	1.3898
363	2.4659	3.8478	1.4173
364	2.4525	3.8252	1.3935
365	2.4537	3.8295	1.3953
366	2.4628	3.8441	1.4075
367	2.4665	3.8508	1.4136
368	2.4647	3.8502	1.4106
369	2.4751	3.8685	1.4258
370	2.4787	3.8722	1.4277
371	2.4763	3.871	1.4246
372	2.4708	3.8649	1.4173
373	2.4726	3.8685	1.4203
374	2.4708	3.8697	1.4216
375	2.4604	3.8563	1.4112
376	2.4506	3.8502	1.4039
377	2.4531	3.8551	1.4051
378	2.4549	3.8606	1.4081
379	2.4519	3.8539	1.3996
380	2.4506	3.8539	1.3971

vi. Day 9 (first 80 data)

time(s)	TGS	ALCOHOL	MQ6
300	2.2224	3.802	1.5821
301	2.2211	3.7928	1.5711
302	2.2279	3.7855	1.5796
303	2.2156	3.7709	1.5796
304	2.1937	3.7678	1.5906
305	2.201	3.7727	1.6059
306	2.1809	3.7684	1.5851
307	2.1729	3.7696	1.5992
308	2.1668	3.7721	1.6138
309	2.1613	3.7703	1.6199
310	2.1534	3.78	1.6218
311	2.1241	3.7861	1.6193
312	2.1149	3.78	1.6242
313	2.1192	3.7941	1.6248
314	2.1192	3.8014	1.6535
315	2.1192	3.8032	1.6742
316	2.1107	3.8057	1.6529
317	2.1082	3.816	1.6401
318	2.0978	3.849	1.648
319	2.0765	3.8362	1.6474
320	2.0954	3.838	1.6486
321	2.0997	3.8466	1.6358
322	2.0746	3.8514	1.6327
323	2.0521	3.8594	1.6303
324	2.2004	3.8649	1.6309
325	2.2211	3.8661	1.6541
326	2.2394	3.8624	1.6572
327	2.2565	3.8588	1.6614
328	2.2578	3.8594	1.6712
329	2.2864	3.86	1.6559
330	2.2864	3.8612	1.6626
331	2.3005	3.8594	1.662
332	2.2614	3.8563	1.6626
333	2.2492	3.8545	1.6565
334	2.2694	3.8563	1.6254
335	2.1125	3.8533	1.6395
336	2.0771	3.8368	1.6126
337	2.0228	3.8362	1.6053
338	2.1375	3.8398	1.5973
339	2.1278	3.8404	1.5925
340	2.1375	3.8343	1.5827
341	2.1418	3.8496	1.5418
342	2.1485	3.8502	1.5357
343	2.1906	3.8533	1.543
344	2.2327	3.8533	1.5418
345	2.2767	3.8508	1.54
346	2.2163	3.8496	1.5387
347	2.2816	3.8478	1.5363
348	2.2639	3.8484	1.5278
349	2.3041	3.8301	1.507
350	2.306	3.8319	1.5088
351	2.2956	3.8325	1.5137
352	2.2773	3.8093	1.4863
353	2.259	3.8063	1.4673
354	2.2993	3.7996	1.5601
355	2.3011	3.7977	1.551
356	2.2919	3.7892	1.5619
357	2.2919	3.7574	1.5717
358	2.2944	3.7428	1.5723
359	2.306	3.7623	1.5992
360	2.2736	3.7465	1.5943
361	2.3133	3.7336	1.6132
362	2.2993	3.7226	1.5967
363	2.3017	3.7184	1.5998
364	2.3048	3.7135	1.6095
365	2.2938	3.7153	1.5174
366	2.2968	3.7129	1.5046
367	2.2639	3.7141	1.4771
368	2.2547	3.7111	1.5497
369	2.2645	3.7208	1.5326
370	2.2504	3.7269	1.5345
371	2.2571	3.7233	1.5345
372	2.295	3.7434	1.5357
373	2.2407	3.7519	1.5589
374	2.2156	3.7526	1.5998
375	2.1931	3.7568	1.6327
376	2.1241	3.758	1.5778
377	2.0673	3.7745	1.6346
378	2.1107	3.8087	1.6224
379	1.98	3.8002	1.6523
380	1.9184	3.7941	1.6608

vii. Day 10(first 80 data)

time(s)	TGS	ALCOHOL	MQ6
300	2.2321	3.755	1.8671
301	2.2236	3.7355	1.8561
302	2.2181	3.7446	1.8451
303	2.2108	3.7538	1.8287
304	2.2065	3.7544	1.8262
305	2.212	3.755	1.8274
306	2.2095	3.7526	1.822
307	2.2108	3.7623	1.8213
308	2.215	3.7593	1.8232
309	2.2126	3.7898	1.8159
310	2.2217	3.7928	1.825
311	2.2266	3.791	1.8293
312	2.2242	3.7812	1.8232
313	2.237	3.7587	1.8354
314	2.2462	3.7684	1.8433
315	2.2468	3.7507	1.8445
316	2.2498	3.7361	1.8464
317	2.2614	3.7306	1.8543
318	2.2889	3.7257	1.8873
319	2.2791	3.7208	1.8738
320	2.2791	3.7172	1.8738
321	2.2889	3.7111	1.8812
322	2.2926	3.6872	1.8854
323	2.2999	3.6341	1.8915
324	2.3017	3.6457	1.8946
325	2.3054	3.6671	1.8934
326	2.3011	3.6512	1.8879
327	2.2987	3.6537	1.883
328	2.2968	3.6622	1.8824
329	2.3011	3.6586	1.8799
330	2.3005	3.6531	1.8799
331	2.2987	3.661	1.8769
332	2.2956	3.6494	1.8708
333	2.2938	3.6171	1.8677
334	2.2956	3.6097	1.8659
335	2.2944	3.6042	1.861
336	2.281	3.5853	1.8409
337	2.281	3.5957	1.8397
338	2.2846	3.5994	1.8415
339	2.2858	3.5804	1.8409
340	2.2816	3.5817	1.8311
341	2.2932	3.589	1.8451
342	2.2944	3.5841	1.8439
343	2.2974	3.6067	1.8451
344	2.2968	3.6091	1.8433
345	2.298	3.6116	1.8384
346	2.2944	3.6378	1.8348
347	2.2956	3.6433	1.8299
348	2.2944	3.6488	1.8281
349	2.2797	3.6512	1.8104
350	2.2834	3.6549	1.8097
351	2.2834	3.6622	1.8079
352	2.2663	3.6702	1.7829
353	2.2633	3.7172	1.778
354	2.259	3.7416	1.7695
355	2.2578	3.7111	1.7658
356	2.2523	3.7074	1.7548
357	2.2279	3.7031	1.7212
358	2.215	3.708	1.7042
359	2.2297	3.7294	1.7225
360	2.2199	3.7312	1.7054
361	2.2095	3.719	1.6907
362	2.2004	3.6995	1.6785
363	2.1973	3.708	1.6718
364	2.1961	3.7379	1.6669
365	2.1943	3.7452	1.662
366	2.1931	3.7519	1.6572
367	2.1931	3.7642	1.6602
368	2.1943	3.7648	1.6559
369	2.201	3.7495	1.6626
370	2.2065	3.7709	1.6675
371	2.204	3.7629	1.6645
372	2.2211	3.7562	1.681
373	2.2266	3.7489	1.6852
374	2.2303	3.7208	1.6846
375	2.2346	3.7257	1.6865
376	2.2358	3.6958	1.6858
377	2.2498	3.6866	1.6999
378	2.2761	3.6805	1.7328
379	2.2742	3.6756	1.7237
380	2.2675	3.6726	1.7145

viii. Day 11(first 80 data)

time(s)	TGS	ALCOHOL	MQ6
300	2.5056	3.5078	1.3007
301	2.5043	3.5096	1.2915
302	2.4946	3.4913	1.286
303	2.5092	3.517	1.2787
304	2.5166	3.5304	1.2519
305	2.5105	3.52	1.2152
306	2.4958	3.4962	1.2299
307	2.508	3.5188	1.2317
308	2.4812	3.4712	1.2104
309	2.4903	3.4883	1.1982
310	2.5062	3.5182	1.1872
311	2.508	3.5255	1.1768
312	2.4995	3.5072	1.1762
313	2.4909	3.4938	1.1744
314	2.4982	3.5066	1.1676
315	2.5086	3.5304	1.1725
316	2.5056	3.5261	1.1744
317	2.5141	3.5395	1.1756
318	2.5233	3.5572	1.1902
319	2.5153	3.5475	1.1829
320	2.5105	3.542	1.2012
321	2.5196	3.5603	1.2116
322	2.5141	3.5487	1.2104
323	2.5135	3.5487	1.2104
324	2.5141	3.5499	1.2091
325	2.5062	3.5377	1.211
326	2.5043	3.5365	1.2104
327	2.4873	3.5102	1.2073
328	2.483	3.5035	1.2146
329	2.4793	3.4986	1.2226
330	2.4769	3.4944	1.2519
331	2.472	3.4864	1.261
332	2.4641	3.4742	1.2183
333	2.4409	3.4339	1.1988
334	2.4354	3.423	1.1872
335	2.436	3.4248	1.1817
336	2.4433	3.4388	1.1823
337	2.4702	3.4901	1.1884
338	2.4726	3.4962	1.1957
339	2.4769	3.5029	1.2146
340	2.4744	3.4999	1.2574
341	2.4708	3.4968	1.2311
342	2.4683	3.4907	1.2372
343	2.461	3.4822	1.2598
344	2.4403	3.448	1.2653
345	2.4305	3.4303	1.2769
346	2.4421	3.451	1.2806
347	2.4219	3.4156	1.2696
348	2.4219	3.4187	1.2769
349	2.4024	3.3845	1.2775
350	2.4116	3.4022	1.2702
351	2.4085	3.3992	1.2683
352	2.4006	3.3869	1.2653
353	2.4061	3.3973	1.2476
354	2.4049	3.3973	1.25
355	2.4079	3.4016	1.2305
356	2.414	3.4187	1.2183
357	2.4152	3.4193	1.2116
358	2.4262	3.4413	1.2055
359	2.4287	3.4462	1.1969
360	2.4299	3.4504	1.175
361	2.4335	3.4571	1.1383
362	2.4311	3.4535	1.1371
363	2.4244	3.4486	1.153
364	2.4195	3.4388	1.153
365	2.4183	3.4376	1.1402
366	2.4158	3.4376	1.1274
367	2.4171	3.4394	1.1145
368	2.4201	3.4449	1.1121
369	2.4219	3.4504	1.1121
370	2.4262	3.4571	1.1078
371	2.4409	3.4822	1.1035
372	2.4561	3.5163	1.0938
373	2.4427	3.4895	1.084
374	2.4616	3.5243	1.0773
375	2.4561	3.5182	1.0767
376	2.4732	3.5475	1.0858
377	2.4677	3.5389	1.0981
378	2.4757	3.5536	1.1182
379	2.4683	3.5444	1.1261
380	2.4665	3.5444	1.1182